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WABASH RIVER BASIN COMPREHENSIVE STUDY COVERING RESERVOIR SITES--ETC(U)

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INTERIM REPORT NO. 2

WABASH RIVER BASIN COMPREHENSIVE STUDY

INDIANA, ILLINOIS AND OHIO

COVERING RESERVOIR SITES
ON
EMBARRASS RIVER, ILLINOIS
AND
CLIFTY CREEK AND PATOKA RIVER, INDIANA

PREPARED BY

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE

CORPS OF ENGINEERS

JANUARY 1964

VOLUME III

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

9 Interim rept. no. 2.

11 Jan 64

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Volume III.

12 64p.

APPENDIX D

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JANUARY 1964

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APPENDIX D

HYDROLOGY AND HYDRAULICS

SECTION I - GENERAL

1. SCOPE.

This appendix provides data and results of studies essential to the development of possible flood control plans on Wabash River downstream from Vincennes, Indiana and on East Fork White River downstream from Columbus, Indiana. The purpose of the appendix is to give complete and comprehensive information on the hydrologic and hydraulic details of reservoir sites on Embarrass River, Clifty Creek and Patoka River.

2. CLIMATOLOGY.

Climate in the portion of Wabash Basin considered herein is generally temperate, with a normal annual rainfall of about 42 inches. Average annual snowfall for this area is about 15 inches. Snow does not remain on the ground for long periods and rarely contributes to floods. Normal temperature is about 56 degrees. Maximum and minimum recorded temperatures at Vincennes, Indiana, which is considered typical of the area, are 111 and -19 degrees. The maximum wind velocity recorded at Indianapolis, Indiana, in miles per hour for an approximate one minute duration is 111.

3. STORMS.

Of the various types of meteorological disturbances which produce storm rainfall in the Wabash River basin, those storms having a quasi-stationary front oriented from west-southwest to east-northeast across the basin have produced the most serious floods on the Wabash River and its tributaries. Storms of this type usually oocur from late winter to early spring when ground conditions are conducive to high runoff. Convective storms, which are productive of the greatest rainfall intensities, generally occur during the summer season, but these storms seldom cause major flooding since their aerial extent is usually limited and they happen at a time when the ground is highly absorptive.

The topography of the basin is such that orographic rainfall does not occur. Although storms are more frequent during the months of October to April, records show that they may occur at any time during the year. A discussion of each of the major storms of record over the Wabash River basin, which occurred prior to 1944, is contained in Appendix I, "Survey Report for Flood Control, Wabash River and Tributaries, Indiana and Illinois," dated 1944. The survey report entitled, "Interim Report on Wabash River and Tributaries at and above the mouth of White River, Indiana, for Flood Control and Allied Purposes," dated 1955, gave data relative to the storm of January-February 1950. The survey report entitled, "Interim Report-Review of Wabash River Basin Exclusive of White Basin Covering Reservoir Sites on Wildcat, Big Pine and Sugar Creek, Indiana for Flood Control and Allied Purposes," dated March 1963 gave data relative to the storms of January - February 1959.

4. PROBABLE MAXIMUM PRECIPITATION.

The probable maximum storm over a particular area for various seasons of the year represents the critical depth-duration-area relations that would result if precipitation during an actual storm in the region were increased to represent the most critical conditions that are considered probable of occurrence. The spillway design floods for the Wabash River Basin are determined by the use of rainfall-excess of the probable maximum storms. Rainfall amounts for areas up to 1,000 square miles and for durations of 6, 12, 24 and 48 hours were taken fromHydrometeorological Report No. 33, United States Weather Bureau and Corps of Engineers. Regarding precipitation of Lincoln Reservoir, a reduction of 5 per cent was made from the amounts given in Report 33 because the irregularity of its shape of basin was not considered consistent with storm isohyetals. Probable maximum precipitation amounts by months and an all-season envelope, for various durations and for three reservoirs are shown in table 1.

5. MAJOR FLOODS OF RECORD.

In Appendix I, "Survey Report for Flood Control, Wabash River and Tributaries," dated 1944, a discussion is presented of 14 great floods in the Wabash River basin which occurred before 1944. The interim reports of 1955 and 1963 furnished data relative to the January - March 1950 and January - February 1959 floods, which were the most damaging floods in the Wabash Basin since the 1944 survey report.

TABLE 1

PROBABLE MAXIMUM PRECIPITATION
(inches)

Duration (hrs)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	All Season
Clifty Creek Reservoir at mile 18.4 on Clifty Creek - drainage area = 140 square miles													
6	4.5	4.6	5.9	8.8	12.4	15.8	18.8	18.5	17.3	14.7	10.1	6.0	18.8
12	7.4	7.5	9.4	12.1	14.7	18.9	22.8	22.7	21.2	17.5	12.7	8.7	23.1
24	10.2	10.1	11.3	14.1	16.8	21.1	25.5	25.4	23.5	20.7	15.1	11.1	25.5
48	13.0	13.0	14.2	17.0	20.0	23.8	28.3	27.9	26.2	23.5	18.4	14.3	28.3
Lincoln Reservoir* at mile 103.1 on Embarrass River - drainage area = 915 square miles													
6	3.4	3.5	4.6	7.1	10.0	12.3	13.1	13.1	12.7	11.1	8.1	5.0	13.6
12	6.0	6.5	7.6	9.9	12.0	15.1	16.3	16.6	16.1	13.9	10.6	7.8	17.2
24	8.4	9.0	9.7	11.8	14.0	17.4	18.8	19.1	18.9	16.9	12.8	10.1	19.7
48	11.1	11.7	12.3	14.6	17.2	20.3	21.4	21.6	21.0	19.6	15.8	13.2	22.4
Patoka Reservoir at mile 118.3 on Patoka River - drainage area = 168 square miles													
6	5.0	5.0	6.4	9.6	13.4	16.5	18.9	18.9	17.7	15.3	11.0	7.1	18.9
12	8.2	8.4	10.3	13.1	16.0	20.0	23.1	23.2	21.8	18.3	14.0	10.2	23.2
24	11.4	11.4	12.4	15.5	18.4	22.5	25.8	25.9	24.3	21.7	16.6	13.1	25.9
48	14.6	14.7	15.6	18.6	22.0	25.4	28.7	28.6	26.9	24.7	20.2	17.0	28.3

* A 5 percent reduction was applied to compensate for the shape of the drainage basin and the direction of its major axis.

SECTION II - LINCOLN RESERVOIR

6. GENERAL.

The dam of Lincoln Reservoir is located 103.0 miles above the mouth of the Embarrass River, a tributary of the Wabash River, and about 10 miles south of Charleston, Illinois. The drainage of the dam site is 915 square miles which comprises about 2.8 percent of the Wabash River Basin. The reservoir control of the drainage area above the damage point of Mt. Carmel, Illinois, is increased from 10.5 percent to 13.7 percent by the addition of Lincoln Reservoir over that of the total of Huntington Reservoir (advance planning). Salamonie Reservoir, Mississinewa Reservoir (each under construction), Mansfield Reservoir, Cagles Mill Reservoir, and Monroe Reservoir (under construction).

7. FLOW AT DAM SITE.

Discharge data determined from staff and recording gages located at Ryans Bridge, between 1938 and 1942, was used as dam site flow. For all other flood periods, flow data at the dam site was determined by the application of effective rainfall to the unit hydrograph, however, flows less than 3,000 c.f.s. were determined by applying drainage area proportion to observed Ste. Marie flows.

8. UNIT HYDROGRAPH OF EMBARRASS RIVER NEAR DIONA, ILLINOIS.

The Embarrass River gaging station at Ryans Bridge near Diona, Illinois, defines the regimen of natural runoff from an area of 918 square miles at a point 100.8 miles above the mouth of the Embarrass River and 2.2. miles downstream of the proposed dam. In December 1938 a water stage recorder and staff gage were installed at the bridge from which a broken record of slightly more than four and one half years of stage data were obtained. Of the storm periods studied, three proved to possess sufficient similarity to indicate that their average would be representative of basin runoff characteristics. Two of those periods studied were of 6-hour unit duration, while the other, an 8-hour unit graph, was converted to 6-hour by S-curve adjustment. Graphic results of the unit hydrograph investigation are shown on plate D-1. Snyder's empirical coefficients, based on the average unit hydrograph near Diona are as follows:

<u>Factor Symbol</u>

L (miles) = 86.0, L_{ca} (miles) = 45.0, $(LL_{ca})^{0.3} = 11.9$

t_R (hours) = 6, t_p (hours) = 21, Time of peak (hours) = 24

$$C_t = \frac{t_p}{(LL_{ca})^{0.3}} = 1.76$$

q_p (c.f.s./sq.mi.) = 6.48, Q_p (c.f.s.) = 5950

C_p 640 = 136, C_p = 0.212

W_{50} (hours) = 104, W_{75} (hours) = 45

T (hours) = 270

9. UNIT HYDROGRAPH OF EMBARRASS RIVER NEAR CAMARGO, ILLINOIS.

The Embarrass River gaging station near Camargo, Illinois defines the regimen of natural runoff from an area of 185 square miles at a point 161.4 miles above the mouth of the Embarrass River and 58.4 miles upstream of the proposed dam. In October 1960, a water stage recorder was installed at the downstream side of a bridge on U. S. Highway 36, 2.0 miles S. W. of Camargo. Approximately three years of stage data were obtained. Of the storm periods studied, two proved to possess sufficient similarity to indicate that their average would be representative of basin runoff characteristics. Both periods were of 6-hour duration, with graphic results of the unit hydrograph investigation shown on plate D-2. Snyder's empirical coefficients, based on the average unit hydrograph near Camargo are as follows:

<u>Factor Symbol</u>

L (miles) = 27.6, L_{ca} (miles) = 12.6, $(LL_{ca})^{0.3}$ = 5.79

t_R (hours) = 6, t_p (hours) = 24, Time of peak (hours) = 27

$C_t = t_p/(LL_{ca})^{0.3} = 4.14$

q_p (c.f.s./sq.mi.) = 11.2, Q_p (c.f.s.) = 2,070

C_p = 0.420

W_{50} (hours) = 42, W_{75} (hours) = 24

T (hours) = 270

10. UNIT HYDROGRAPH AT DAM SITE.

Due to the close proximity of the dam site to the gaging station at Ryans Bridge on the Embarrass River near Diona, Illinois, the determination of a unit graph at the proposed site was accomplished through the application of drainage area ratio 915/918 to the unit graph at the gaging station. Resultant 6-hour unit graph of Embarrass River at the dam site is presented on plate D-3.

11. TAILWATER RATING CURVES.

The tailwater curve at mile 102.45 for the dam of Lincoln Reservoir was developed by the use of backwater computations, augmented by slope-area computations. The resulting tailwater curve was partially verified by relation to very fragmentary records at Ryans Bridge gaging station, which is approximately two miles downstream of the tailwater rating.

12. CHANNEL CAPACITY.

Based on a study of the 103 miles of Embarrass River below the dam site, it is estimated that a flow as high as 3,000 cubic feet per second can be carried by the stream between miles 20 and 25 without sustaining appreciable damage in the flood plain. Critical channel capacity downstream from the dam site, however, is only 2,000 cubic feet per second.

13. AREA AND CAPACITY OF RESERVOIR.

Area and capacity determination for Lincoln Reservoirs is based on U. S. Geological Survey topography, the horizontal scale of which is 162,500 with a contour interval of 10 feet. Volume of reservoir capacity shown in table 2 was computed by planimetered horizontal areas. Capacity in inches runoff from the drainage area is based on a reservoir basin area of 915 square miles.

TABLE 2
AREA AND CAPACITY
LINCOLN RESERVOIR, EMBARRASS RIVER, ILLINOIS
MILE 103

Elev. (ft. m.s.l.)	Area (acres)	Storage Capacity (acre-feet)	Storage Capacity (inches on drainage area)	Elev. (ft. m.s.l.)	Area (acres)	Storage Capacity (acre-feet)	Storage Capacity (inches on drainage area)
541	0	0	0	596	6760	126765	2.60
542	2	1	0.00002	598	7250	140775	2.88
544	8	11	0.0002	600	7822	155847	3.19
546	22	41	0.0008	602	8330	171999	3.52
548	52	115	0.002	604	8870	189199	3.88
550	116	283	0.006	606	9470	207539	4.25
552	194	593	0.01	608	10050	227059	4.65
554	298	1085	0.02	610	10749	247858	5.08
556	424	1807	0.04	612	11521	270128	5.53
558	574	2805	0.06	614	12371	294020	6.02
560	749	4128	0.08	616	13270	319661	6.55
562	977	5854	0.12	618	14200	347131	7.11
564	1187	8018	0.16	620	15183	376514	7.71
566	1437	10642	0.22	622	16240	407937	8.36
568	1703	13782	0.28	624	17480	441657	9.05
570	1983	17468	0.36	626	18800	477937	9.79
572	2290	21741	0.44	628	20350	517087	10.60
574	2620	26651	0.55	630	22150	559587	11.47
576	2950	32221	0.66	632	24230	605967	12.42
578	3300	38471	0.79	634	27235	657432	13.47
580	3632	45403	0.93	636	31500	716167	14.67
582	3985	53020	1.09	638	38000	785667	16.10
584	4310	61315	1.26	640	50571	874238	17.91
586	4660	70285	1.44	642	65000	989809	20.28
588	5020	79965	1.64	644	79500	1134309	23.24
590	5400	90385	1.85	646	94300	1308109	26.80
592	5830	101615	2.08	648	108900	1511309	30.97
594	6280	113725	2.33	650	123067	1743276	35.72

14. MINIMUM POOL.

In order to meet the requirements of recreation, fish and wildlife, and siltation, minimum pool is established at elevation 582.4, a level that provides an area of 4,050 acres and a volume of 55,020 acre-feet, which is equivalent to 1.13 inches runoff from the drainage area. Sedimentation records indicate a loss of about 494 acre-feet of storage annually, which, when accumulated over a period of approximately 111 years, would fill the reservoir pool to elevation 582.4. The annual loss represents about 0.9 percent of the minimum pool storage.

15. WATER SUPPLY AND WATER QUALITY STORAGE.

In order to provide firm flows of 10 c.f.s. for water supply and 15 c.f.s. for water quality, a storage of 5,300 acre-feet between pool elevation 582.7 and conservation pool elevation 584.0 would be reserved for these purposes during extremely low periods of natural flow. The critical low flow period for which 5,300 acre-feet is necessary in order to produce these regulated flows is that of 1953-1954. In addition, the storage between elevation 582.7 and 582.4 would be reserved for the replacement of Charleston water supply reservoir storage estimated at 1,000 acre-feet.

16. RESERVOIR STORAGE FOR FLOOD CONTROL.

The maximum flood control pool was established at elevation 629.0 with a total storage of 538,315 acre-feet, equal to 11.03 inches runoff. The flood control storage below pool elevation 629.0 and above top of conservation pool (elevation 584.0) is 477,000 acre-feet, which is equivalent to a runoff of 9.77 inches.

17. RESERVOIR REGULATION PLAN.

The regulation table which gives allowable releases to meet flood control requirements downstream from Lincoln Reservoir is based on critical channel capacity of 3,000 cubic feet per second at mile 20 - 25 on the embarrass River. Flow from the uncontrolled drainage area upstream from the critical damage point was determined by drainage area proportion of its area to that of the area of the Oblong gage. The allowable reservoir releases indicated in the regulation table are the difference between critical channel capacity and the flow from the uncontrolled area. The reservoir regulation table which is based on natural flows at Oblong and which is a part of table 3 was developed for use of the study only. In addition, reservoir regulation is based on river conditions at damage centers at Mt. Carmel, Illinois, and Evansville, Indiana. Controlling stages at U. S. Weather Bureau gage at Mt. Carmel are 14 feet on a rising river and 20 feet on a falling river. Controlling stages at U. S. Weather Bureau gage at Evansville are 35 feet on a rising river and 43 feet on a falling river. The controlling stages are based on the beginning of damage for reaches of

the river represented by the gages with due allowance for time of travel from Lincoln Reservoir to these damage points. Table 3, "Schedule of Regulation, Lincoln Reservoir," gives the details of procedure for regulation of the reservoir for flood control.

18. UTILIZATION OF FLOOD CONTROL STORAGE.

Regulation of the reservoir so as to store excess runoff of fourteen flood periods extending from 1927 to 1955, indicated that the highest reservoir pool attained was elevation 632.0 which occurred during the 1950 flood period. This reservoir pool elevation represents utilization of all of the flood control storage plus 68,120 acre-feet of storage above the spillway crest. Table 4 shows results of the reservoir regulation studies.

TABLE 3

LINCOLN RESERVOIR

SCHEDULE OF REGULATION

FLOOD CONTROL ONLY

Schedule	(Controlling Stages (feet)) Wabash River Mt. Carmel	Ohio River Evansville	Range in Pool Elevation (feet)	Regulation
	(All stages must exist for application of Schedules A and B)			
A	Below 14R or Below 20F	Below 35R or Below 43F	Conservation Pool (584)	Release inflow necessary to maintain pool, provided allowable release indicated in Regulation Table is not exceeded.
B	Below 14R or Below 20F	Below 35R or Below 43F	(584 - 629)	Discharge allowable release indicated in Regulation Table.
	(Any one condition to exist for application of Schedule C)			
C	14R and above or 20F and above	35R and above or 43F and above	(584 - 629)	Release at constant rate of 500 c.f.s.
D	Control Stations no longer considered		Above 629.0	When pool elevation 629.0 is attained and likely to be exceeded, release all inflow, provided a flow of 2,000 c.f.s. is not exceeded. When inflow rate exceeds 2,000 c.f.s., store inflow in excess of 2,000 c.f.s. outflow, (conduit + spillway) until elevation 634.8 is attained, after which conduits will be closed and remainder of flood routed through 100-foot uncontrolled spillway. When inflows into reservoir are diminishing and pool stage is between elevation 634.8 and 629.0, release (conduit + spillway) at rate of 2,000 c.f.s. until pool elevation 629.0 is attained. Downstream controls are not considered.

REGULATION TABLE

Natural Flow (c.f.s.) N. Fk. Embarrass River at Oblong, Illinois	Allowable Reservoir Release (c.f.s.)
Below 300	2,000
300 - 400	1,700
400 - 500	1,300
500 - 600	900
Above 600	500

TABLE 4
FLOOD CONTROL STORAGE UTILIZATION DATA
LINCOLN RESERVOIR

Storage period		Accumulated	Percent	Maximum	Peak	Peak
Flood date	Date of maximum stage	storage above conservation pool (ac.ft.)*	of storage utilization **	reservoir pool elev. (ft.m.s.l.)	reservoir inflow (cfs)	reservoir outflow (cfs)
Jan-Feb 1927	15 Feb 1927	112,090	23.5	602.2	4,880	2,000
Jan-Feb 1930	27 Jan 1930	161,380	33.8	607.7	9,150	2,000
Mar-Jun 1933	31 May 1933	386,340	81.0	624.3	13,300	2,000
Feb-Apr 1936	7 Apr 1936	50,050	10.5	593.6	4,320	2,000
Dec-Mar 1937	11 Feb 1937	211,400	44.3	612.2	8,000	2,000
Jan-May 1939	30 Apr 1939	343,250	72.0	621.8	14,500	2,000
Apr-May 1940	5 May 1940	36,420	7.6	591.3	3,670	2,000
Dec-Jan 1943	11 Jan 1943	38,430	8.1	591.7	3,750	2,000
May-Jul 1943	3 Jun 1943	387,620	81.3	624.4	16,150	2,000
Feb-May 1945	18 Apr 1945	196,450	41.2	610.9	8,650	2,000
Mar-May 1948	26 Apr 1948	197,720	41.5	613.0	10,250	2,000
Dec-Aug 1950	27 Feb 1950	545,120	114.3***	632.0	21,900	2,000
Dec-Mar 1952	14 Feb 1952	82,340	17.3	598.4	4,000	2,000
Feb-Apr 1955	6 Mar 1955	2,700	0.6	584.6	2,570	2,000

* Conservation Pool at Elevation 584.0.
** Flood Control Storage at full reservoir (elev. 629.0) is 477,000 acre-feet.
*** Includes Spillway surcharge storage.

19. SEASONAL LOW FLOW REGULATION PLAN.

Seasonal low flow regulation is predicated on reducing the allocated flood control storage during the summer months and, thereby, raise the water surface in the interest of general recreation and make available storage for increasing the natural flow between 1 April and 30 November. The method is as follows: Starting 1 April with pool at conservation level the water surface in the reservoir would be raised as rapidly as inflows will permit so as to attain the seasonal pool elevation by 1 May. The seasonal pool elevation is set at such a level that it will be attained three-fourths or more of the years. With pool elevations at or near seasonal level, storage can be released when necessary to satisfy minimum flow objectives downstream. Seasonal pool level for Lincoln Reservoir was set at elevation 596 which provides 65,450 acre-feet or 1.34 inches runoff of storage above the top of conservation pool (elevation 584.0). Beginning 1 September and ending 30 November the pool would be depleted while meeting low flow and flood control requirements so as to be down to conservation pool at the end of November. The water surface increases from an area of 4,310 acres at conservation pool level to 6,760 acres at seasonal pool level.

20. STANDARD PROJECT STORM.

The Standard Project Storm, determined by the method outlined in Civil Engineer Bulletin No. 52-8, Corps of Engineers, dated March 26, 1952, has a volume which is equivalent to 13.01 inches rainfall and 11.11 inches runoff and is shown by 6-hour rainfall amounts in table 5. The Standard Project Storm Isohyetal Pattern was superimposed over the Lincoln Reservoir drainage basin to obtain maximum rainfall, as shown on plate D-5. To obtain the rainfall-excess amounts, the storm was modified by an initial loss of 0.40 inch and an infiltration rate of 0.025 inch per hour. The infiltration and rainfall-excess amounts are also shown on table 5.

21. STANDARD PROJECT FLOOD.

The Standard Project Storm rainfall-excess was applied to the Lincoln natural unit hydrograph on plate D-3, and an assumed base flow of 1,000 cubic feet per second was added. The resulting hydrograph was routed through the reservoir in accordance with the schedule of regulation presented in table 3, assuming the reservoir at conservation pool elevation 584 and the downstream control stations all above flood stage at the start of the Standard Project Storm. Outflow was regulated to maintain 500 cubic feet per second discharge and the remainder of the inflow was stored until spillway crest was reached and then the conduit was opened further until a discharge of 2,000 cubic feet per second was released through a combination of conduit and spillway. The reservoir pool crested at elevation 631.82, which is 2.82 feet above spillway crest. The maximum inflow of 62,800 cubic feet per second was reduced to 2,000 cubic feet per second. Inflow, outflow, and pool elevation hydrographs are shown on plate D-6.

TABLE 5
STANDARD PROJECT STORM
RAINFALL AND RAINFALL-EXCESS
ABOVE
LINCOLN DAMSITE

Time in Hours	6-Hour Rainfall (inches)	Infiltration Loss (inches)	Rainfall Excess (inches)
0-6	0.02	0.02	0
6-12	0.06	0.06	0
12-18	0.30	0.30	0
18-24	0.04	0.04	0
24-30	0.11	0.11	0
30-36	0.27	0.15	0.12
36-42	1.33	0.15	1.18
42-48	0.17	0.15	0.02
48-54	0.58	0.15	0.43
54-60	1.45	0.15	1.30
60-66	7.18	0.15	7.03
66-72	0.90	0.15	0.75
72-78	0.03	0.03	0
78-84	0.09	0.09	0
84-90	0.43	0.15	0.28
90-96	0.05	0.05	0
TOTAL	13.01	1.90	11.11

22. OUTLET WORKS.

The outlet works consist of regulating discharge structures and a stilling basin. It is desirable to select a size of conduit such that a discharge of critical bankfull (2,000 c.f.s.) will obtain at or near minimum reservoir pool stage. A 10-foot diameter circular conduit, which is estimated to have a discharge of about 2,720 cubic feet per second at pool elevation 584.0 and 3,980 cubic feet per second at pool elevation 629 was adopted. The conduit is located near the left abutment of the dam. Three rectangular gates, each 4.0 feet wide by 8.0 feet high, are provided to regulate flow in the conduit. The invert of the conduit at exit is at elevation 538.0. The conduit of 78.54 square feet cross-sectional area has a longitudinal slope of 0.22 percent. Plate D-7 gives the discharge rating of the 10-foot conduit. The stilling basin and parabolic vertical transition from the downstream end of conduit are designed on the basis of a reservoir outflow of 2,000 cubic feet per second. Pool elevation 629.0 was adopted as the critical stage for stilling basin design because the partial gate openings required to release 2,000 c.f.s. creates the highest velocity of flow that can be expected for this release. The discharge of 2,000 cubic feet per second at pool elevation 629.0 is accomplished by opening two gates about 4 feet each. With discharge control at the gates, flow gradient estimates made downstream from the gate indicated that the conduit would have water flowing at a depth of about 6 feet and an average velocity of 40.65 feet per second at the exit. The parabolic floor curve of the vertical transition from exit of conduit to the stilling basin was determined as indicated in paragraph 2-23C, Engineering Manual, "Hydraulic Design, Reservoir Outlet Structures," as is defined by equation

$$y = -(0.002150\, x + 0.006353\, x^2),$$

where x and y are horizontal and vertical coordinates measured from the beginning of curve in feet. Details of stilling basin are shown on plates D-8 and D-9. The tailwater level corresponding to a flow of 2,000 cubic feet per second is estimated to be at elevation 545.05. The jump-height, to satisfy the momentum equation, based on a width of about 25 feet and a floor elevation 533.75 is computed at elevation 545.05. Assurance that the hydraulic-jump will occur in the basin is afforded by a jump-height computation made upstream of the end sill, for the conditions of stilling basin design and a reduction in D_2 of 10 percent for head losses resulting from floor, walls, baffle piers and end sill, which indicated that the jump-height would meet the tailwater height. The length of the stilling basin was established at 47.5 feet which is about 4.2 times the design jump-height (11.3 feet). The retreat channel which connects the stilling basin with the natural stream is about 1,100 feet in length. The bottom of the channel is 35 feet in width and side slopes are 1 on 2. The retreat channel bottom would have a longitudinal slope of about 0.1 percent from the top of end sill where its elevation is 535.75 to the confluence with the natural stream at mile 102.5 where its elevation

is 535 feet. The maximum velocity in the channel for flows up to 2,000 cubic feet per second is estimated at less than 6.2 feet per second. Since the retreat channel is excavated in earth, riprap will be placed for 100 feet downstream from the end sill of the stilling basin in order to prevent erosion of the channel.

23. SPILLWAY.

A channel spillway is planned with the cut all in earth since no rock is available. The width of channel decided upon is 100 feet at the base, with side slopes of 3 horizontal and 1 vertical. The cut is about 2,000 feet long and has a level base at elevation 629, the top of the flood control pool. A continuous section of concrete pavement about 100 feet wide with steel sheet piling cutoff at each side may be placed in the spillway if excessive velocity of flow develops into a deterioration of channel bottom.

A discharge rating was developed for a spillway width of 100 feet with certerline as shown on plate 3 report. For purpose of this report, the bottom was considered flat the full length. It was assumed that the control section would be at the downstream end of the spillway. Critical discharges were computed for various depths of flow at the control section, and flow-lines were computed to the reservoir pool. A rating curve of reservoir pool versus spillway discharge was then drawn. Discharge at the control section was computed by the critical flow formula,

$$Q = A\left(\frac{Ag}{T}\right)^{1/2}$$

where:

A = area in square feet

g = acceleration of gravity in feet per second per second

T = top width of section in feet

Q = discharge in cubic feet per second

The following losses were estimated between the control section and reservoir pool.

(a) At entrance to spillway the loss was assumed to be one-tenth of the velocity head.

(b) Friction losses were estimated by use of Manning's formula, assuming a coefficient of roughness of 0.025 for earth. It is planned that the spillway surfaces will be well maintained. The discharge rating curve for the 100-foot spillway, and other spillway characteristics are shown on plate D-10.

24. SELECTION OF PROBABLE MAXIMUM STORM.

The basis of seasonal variations of the probable maximum rainfall are shown in paragraph 4 and depth values are given in table 1. The seasonal storm for spillway design is that storm runoff which when routed through the spillway will produce the maximum reservoir pool stage when the reservoir pool elevation at the beginning of the spillway design flood is the maximum pool for the same season obtained from routings made according to the Reservoir Regulation Plan. Routings made since 1927 indicate that the 1949-1950 flood would produce the highest pool stages in Lincoln Reservoir between March and July. Data shown below indicates the maximum starting pool elevations by months and the corresponding probable maximum rainfalls.

Month	Maximum reservoir pool elevation at start of spillway flood (ft. m.s.l.)	Probable maximum precipitation (inches)
March	632.0	12.3
April	631.3	14.6
May	629.0	17.2
June	624.9	20.3
July	623.4	21.4

On the basis of preliminary routings for Lincoln Reservoir it was determined that the most critical combination of starting pool storm runoff would occur in May.

Paragraphs 25 through 32 give the results of spillway flood determinations and the spillway routings.

25. RUNOFF OF PROBABLE MAXIMUM STORM

Based on studies of infiltration during late spring and summer, a minimum rate of 0.05 inch per hour was selected. Initial loss was assumed to be 0.5 inch. Six-hour ordinates of the May envelope of the probable maximum storm were arranged in the sequence which would produce maximum peak discharge in the design flood hydrograph. Table 6 shows the distribution of rainfall, infiltration and rainfall-excess by six-hour periods.

TABLE 6
PROBABLE MAXIMUM MAY DISTRIBUTION FOR
SPILLWAY DESIGN FLOOD LINCOLN RESERVOIR

Time in hours	6-hour rainfall (inches)	Infiltration loss (inches)	Rainfall excess (inches)
0-6	0.73	0.59*	0.14
6-12	0.87	0.30	0.57
12-18	1.19	0.30	0.89
18-24	2.01	0.30	1.71
24-30	9.98	0.30	9.68
30-36	0.94	0.30	0.64
36-42	0.70	0.30	0.40
42-48	0.79	0.30	0.49
TOTAL	17.21	2.69	14.52

$* \; 0.50 + \frac{.73-.50}{.73} \times 6 \times .05 = 0.59$

26. INFLOW UNIT HYDROGRAPHS.

The inflow unit hydrographs developed for spillway design were based on an average pool level above elevation 635, which is believed to provide sequence of inflow likely to occur during the spillway floods. The reservoir drainage area was subdivided into the following areas:

(1) The area above the head of reservoir, 690.0 square miles;

(2) Five areas adjacent to the reservoir surface totaling 180.21 square miles;

(3) Reservoir surface area 44.79 square miles.

Regimen of flood runoff is defined by inflow unit hydrographs developed for runoff originating above head of the reservoir pool and for runoff contributing to the pool from individual areas along its periphery.

27. UNIT HYDROGRAPH FOR BASIN ABOVE HEAD OF RESERVOIR.

The area above the head of reservoir, which is 690 square miles, is designated as 1-A. Area 1-A unit hydrograph was developed by the use of Snyder's method. Snyder coefficients, other than those measured for L and L_{ca} were derived through the correlation of data from other unit hydrogrphs of adjacent areas of Diona and Camargo, Illinois, which are shown on plates 1 and 2, respectively, and have similar runoff characteristics. The coefficients C_t and C_p, thus derived, together with the coefficients $(LL_{ca})^{0.3}$, which were used in the evaluation of other coefficients such as "lag" time, hydrograph widths (hours) at 50 and 75 percent of peak discharge are shown in table 7. Through use of the above mentioned coefficients, the basic unit hydrograph was developed by adopting the pattern most consistent with a corresponding S-curve hydrograph, as shown in table 7. Since storms of a magnitude approaching the probable maximum produce peak discharges of the unit hydrograph that are consistently higher than thos computed from records of minor floods, the peak of hydrograph L-A was increased arbitrarily by 25 and 50 percent. Thus hydrographs 1-B and 1-C each having the same volume as hydrograph 1-A but of different degrees of concentration for the total area at the head of Lincoln Reservoir, were developed. Pertinent unit hydrograph data relative to the subarea 1, including 3-hour instantaneous values of unit and S-curve hydrographs are shown in table 7.

TABLE 7
UNIT AND S-CURVE HYDROGRAPHS FOR HEAD OF RESERVOIR TOTAL AREA
LINCOLN, RESERVOIR, EMBARRASS RIVER, ILLINOIS

Location: Area #1, Drainage Area = 690 sq. mi.
Snyder's equations: (Separate determination for each sub-area)
S-curve: Q_{max} = (drainage area)(26.889) ($24/t_R$) = 74,214 c.f.s.

GRAPH 1-A	GRAPH 1-B	GRAPH 1-C
t_R = 6 hrs	t_R = 6 hrs	t_R = 6 hrs
t_{pR} = 22 hrs	t_{pR} = 19 hrs	t_{pR} = 16 hrs
q_{pR} = 8.05 cfs/sq.mil.	q_{pR} = 10.03 cfs/sq.mil.	q_{pR} = 12.05 cfs/sq.mi.
W_{50} = 74 hrs	W_{50} = 55 hrs	W_{50} = 49 hrs
W_{75} = 35 hrs	W_{75} = 28 hrs	W_{75} = 23 hrs
T = 274 hrs	T = 246 hrs	T = 218 hrs

Time in hours	Unit hydrograph (c.f.s.)	S-curve hydrograph (c.f.s.)	Unit hydrograph (c.f.s.)	S-curve hydrograph (c.f.s.)	Unit hydrograph (c.f.s.)	S-curve Hydrograph (c.f.s.)
0	0	0	0	0	0	0
3	500	500	729	729	900	900
6	1250	1250	1814	1814	2900	2900
9	2210	2710	2900	3629	4750	5650
12	3199	4449	4500	6314	6550	9450
15	4239	6949	5700	9329	7900	13550
18	4999	9448	6450	12764	8280	17730
21	5379	12328	6900	16229	8260	21810
24	5529	14977	6880	19644	8050	25780
27	5540	17868	6750	22979	7630	29440

TABLE 7 (Cont'd)

Time in hours	GRAPH 1-A Unit hydrograph (c.f.s.)	GRAPH 1-A S-curve hydrograph (c.f.s.)	GRAPH 1-B Unit hydrograph (c.f.s.)	GRAPH 1-B S-curve hydrograph (c.f.s.)	GRAPH 1-C Unit hydrograph (c.f.s.)	GRAPH 1-C S-curve hydrograph (c.f.s.)
30	5490	20467	6490	26134	7000	32780
33	5402	23270	6130	29109	6330	35770
36	5293	25760	5720	31854	5700	38480
39	5017	28287	5280	34389	5230	41000
42	4807	30567	4880	36734	4880	43360
45	4571	32868	4580	38969	4620	45620
48	4376	34943	4320	41054	4420	47780
51	4170	37038	4100	43069	4230	49850
54	3994	38937	3920	44974	4040	51820
57	3829	40867	3760	46829	3830	53680
60	3693	42630	3610	48584	3620	55440
63	3559	44426	3470	50299	3390	57070
66	3443	46073	3340	51924	3160	58600
69	3328	47754	3200	53499	2910	59980
72	3221	49294	3050	54974	2650	61250
75	3098	50852	2900	56399	2400	62380
78	2971	52265	2740	57714	2170	63420
81	2827	53679	2580	58979	1970	64350
84	2680	54945	2410	60124	1780	65200
87	2526	56205	2250	61229	1610	65960
90	2378	57323	2090	62214	1460	66660
93	2235	58440	1940	63169	1320	67280
96	2108	59431	1790	64004	1190	67850
99	1975	60415	1650	64819	1080	68360
102	1856	61287	1520	65524	1000	68850
105	1734	62149	1390	66209	914	69274

TABLE 7 (Cont'd)

Time in hours	GRAPH 1-A Unit hydrograph (c.f.s.)	GRAPH 1-A S-curve hydrograph (c.f.s.)	GRAPH 1-B Unit hydrograph (c.f.s.)	GRAPH 1-B S-curve hydrograph (c.f.s.)	GRAPH 1-C Unit hydrograph (c.f.s.)	GRAPH 1-C S-curve hydrograph (c.f.s.)
108	1626	62913	1300	66824	830	69680
111	1514	63663	1210	67419	780	70054
114	1415	64328	1120	67944	730	70410
117	1313	64976	1030	68449	680	70734
120	1225	65553	960	68904	630	71040
123	1144	66120	890	69339	590	71324
126	1074	66627	820	69724	550	71590
129	1001	67121	750	70089	510	71834
132	943	67570	700	70424	470	72060
135	893	68014	650	70739	440	72274
138	843	68413	600	71024	410	72470
141	791	68805	550	71289	380	72650
144	743	69156	510	71534	350	72820
147	702	69507	470	71759	325	72979
150	662	69818	430	71964	300	73120
153	622	70129	400	72159	275	73254
156	582	70400	370	72334	250	73370
159	561	70680	340	72499	230	73484
162	522	70922	320	72654	210	73580
165	491	71171	300	72799	190	73674
168	462	71384	280	72934	170	73750
171	431	71602	260	73059	150	73824
174	401	71785	240	73174	135	73885
177	371	71973	220	73279	120	73944
180	351	72136	205	73379	105	73990
183	331	72304	190	73469	90	74034
186	312	72448	175	73554	80	74070
189	291	72595	160	73629	70	74104

TABLE 7 (Cont'd)

Time in hours	GRAPH 1-A Unit hydrograph (c.f.s.)	GRAPH 1-A S-curve hydrograph (c.f.s.)	GRAPH 1-B Unit hydrograph (c.f.s.)	GRAPH 1-B S-curve hydrograph (c.f.s.)	GRAPH 1-C Unit hydrograph (c.f.s.)	GRAPH 1-C S-curve hydrograph (c.f.s.)
192	276	72724	150	73704	60	74130
195	260	72855	140	73769	50	74154
198	245	72969	130	73834	40	74170
201	231	73086	120	73889	30	74184
204	216	73185	110	73944	25	74195
207	200	73286	100	73984	20	74204
210	191	73376	90	74034	15	74210
213	181	73467	80	74069	10	74214
216	171	73547	70	74104	4	74214
219	160	73627	60	74129	0	74214
222	151	73698	50	74154		
225	141	73768	40	74169		
228	130	73828	30	74184		
231	120	73888	25	74194		
234	110	73938	20	74204		
237	100	73988	15	74209		
240	96	74034	10	74214		
243	80	74068	5	74214		
246	70	74104	0	74214		
249	60	74128				
252	50	74154				
255	41	74169				
258	30	74184				
261	25	74194				
264	20	74204				
267	15	74209				
270	10	74214				
273	5	74214				
276	0	74214				

28. UNIT HYDROGRAPHS FOR AREAS ADJACENT TO RESERVOIR SURFACE.

Area 2 was divided into five sub-areas aggregating to 180.21 square miles, the smallest of which is 6.00 square miles and the largest 111.66 square miles. Unit hydrographs for these areas, lying along the periphery of the reservoir pool, were developed by synthetic methods, due to the absence of observed flow records for each of the respective streams. Unit hydrograph values thus derived were for peak discharge, time of peak, the discharge at twice the time of peak and base time. These values were related to slope of the valley and size of the drainage area for the condition of uniform distribution of rainfall. Ordinates of the three one-hour unit graphs were combined into a single one-hour unit graph and this converted into a unit hydrograph of 6-hour duration of rainfall-excess. The resultant hydrograph, was then combined with two 6-hour unit hydrographs developed by Snyder's method for the remaining areas. The resultant 6-hour unit hydrograph, designated 2, having a peak flow of 3,550 cubic feet per second or 197 cubic feet per second per square mile of drainage areas is shown in table 8.

TABLE 8
TOTAL UNIT HYDROGRAPH
FOR AREAS ADJACENT RESERVOIR POOL

LINCOLN RESERVOIR

Time in hours	Discharge (c.f.s.)	Time in hours	Discharge (c.f.s.)
0	0	120	150
3	2057	123	142
6	3549	126	132
9	2339	129	123
12	1850	132	115
15	1982	135	108
18	2060	138	101
21	2094	141	96
24	2032	144	90
27	1889	147	84
30	1693	150	77
33	1483	153	71
36	1282	156	65
39	1130	159	61
42	1014	162	56
45	924	165	52
48	835	168	49
51	763	171	45
54	701	174	40
57	648	177	36
60	600	180	33
63	558	183	30
66	512	186	28
69	480	189	25
72	446	192	21
75	414	195	18
78	382	198	15
81	359	201	13
84	332	204	12
87	310	207	11
90	289	210	10
93	271	213	8
96	253	216	7
99	238	219	6
102	221	222	5
105	209	225	4
108	195	228	3
111	183	231	2
114	169	234	1
117	159	237	0

29. RUNOFF FOR RESERVOIR POOL AREA.

Since the rate of runoff for the surface of the reservoir pool is equal to the rate of rainfall, one inch of rainfall in six hours over 44.8 square miles of pool area represents a uniform discharge of 4819 c.f.s. from area 3. Accordingly, for a rainfall of 1-inch in 6 hours the following runoff results:

Time in hours	Discharge (c.f.s.)
0-3	4819
3-6	4819

30. SPILLWAY FLOODS.

Since the volume and time and degree of concentration of runoff into the reservoir cannot be ascertained with a high order of accuracy, it is desirable to estimate the extent of variations in maximum reservoir levels that would obtain from varied basic assumptions regarding runoff. By application of the "rainfall-excess" of table 6 to unit hydrographs 1-A and 2, plus the application of "rainfall" from the same table to unit graph 3, the basic provisional spillway flood, designated hydrograph A, was developed. Hydrographs of design storms that reflect greater concentrations of runoff than that indicated for the provisional spillway flood were developed through application of unit graphs 1-B and 1-C, respectively, to increments of rainfall-excess covering the 12-hour period of greatest intensity and substituted in proper time relation for the corresponding runoff computed by use of unit graph 1-A. Hydrographs A, B, and C shown in table 9 were developed by procedures outlined above. Comparative data, showing maximum reservoir inflow 109,400 c.f.s. for the basic provisional spillway flood, peak flow for greater concentration of runoff, and other characteristics, are presented in table 10.

TABLE 9
HYPOTHETICAL HYDROGRAPHS OF RUNOFF FROM SPILLWAY
DESIGN STORM
LINCOLN RESERVOIR, EMBARRASS RIVER, ILLINOIS

Time in hours	Inflow hydrograph 3-hr. average values (c.f.s.)			Time in hours	Inflow hydrograph 3-hr. average values (c.f.s.)		
	A*	B**	C		A*	B**	C
0-3	1000	1000	1000	114-117	40243	36927	29650
3-6	4657	4657	4657	117-120	37884	34519	27377
6-9	5058	5058	5058	120-123	35744	32141	25357
9-12	6416	6416	6416	123-126	33569	29912	23425
12-15	8052	8052	8052	126-129	31551	27859	21739
15-18	11076	11076	11076	129-132	29555	25857	20268
18-21	13792	13792	13792	132-135	27746	24099	18780
21-24	20768	20959	20961	135-138	26017	22522	17592
24-27	26316	26947	27988	138-141	24314	21014	16464
27-30	76910	78979	81478	141-144	22765	19581	15465
30-33	105708	111215	120308	144-147	21332	18279	14506
33-36	72886	80868	98737	147-150	20046	17102	13651
36-39	76865	90443	111985	150-153	18804	15954	12823
39-42	85977	102199	126261	153-156	17686	14849	12028
42-45	97175	114522	136144	156-159	16661	13868	11256
45-48	104759	121698	138673	159-162	15783	13004	10533
48-51	108204	124325	137703	162-165	14876	12134	9950
51-54	104471	118408	128983	165-168	14118	11361	9328
54-57	102136	113715	120829	168-171	13320	10612	8808
57-60	99020	107835	111228	171-174	12561	9944	8241
60-63	95403	101263	102052	174-177	11889	9288	7739
63-66	91098	94664	93870	177-180	11228	8706	7246
66-69	86351	88113	87757	180-183	10590	8167	6769
69-72	81716	82392	82571	183-186	10041	7661	6330
72-75	77758	77600	78417	186-189	9531	7172	5919
75-78	73823	73375	74559	189-192	8946	6786	5534
78-81	70363	69614	70871	192-195	8481	6408	5160
81-84	67007	66248	67154	195-198	8011	6042	4803
84-87	64098	63216	63489	198-201	7524	5675	4468
87-90	61349	60376	59727	201-204	7066	5323	4165
90-93	58904	57815	56040	204-207	6673	5016	3880
93-96	56501	55185	52107	207-210	6319	4719	3592
96-99	54360	52535	48315	210-213	5992	4450	3348
99-102	52035	49967	44561	213-216	5671	4183	3129
102-105	49821	47278	41068	216-219	5358	3938	2913
105-108	47282	44711	37841	219-222	5103	3719	2694
108-111	45001	42061	34957	222-225	4833	3515	2495
111-114	42467	39418	32152	225-228	4602	3332	2320

TABLE 9 (Cont'd)

Time in hours	Inflow hydrograph 3-hr. average values (c.f.s.)			Time in hours	Inflow hydrograph 3-hr. average values (c.f.s.)		
	A*	B**	C		A*	B**	C
228-231	4363	3147	2173	276-279	1765	1171	1171
231-234	4145	2975	2058	279-282	1642	1149	1149
234-237	3942	2801	1939	282-285	1513	1125	1125
237-240	3783	2634	1829	285-288	1408	1106	1106
240-243	3606	2456	1704	288-291	1327	1082	1082
243-246	3433	2292	1605	291-294	1256	1068	1068
246-249	3279	2130	1538	294-297	1182	1056	1056
249-252	3118	1974	1491	297-300	1122	1045	1045
252-255	2948	1823	1445	300-303	1035	1035	1035
255-258	2792	1704	1402	303-306	1026	1026	1026
258-261	2636	1600	1355	306-309	1016	1016	1016
261-264	2490	1511	1323	309-312	1012	1012	1012
264-267	2358	1412	1281	312-315	1006	1006	1006
267-270	2214	1328	1251	315-318	1004	1004	1004
270-273	2044	1253	1224	318-321	1000	1000	1000
273-276	1905	1197	1197				

* Basic provisional spillway flood runoff
** Adopted as spillway design flood

TABLE 10
SPILLWAY FLOOD DATA
LINCOLN RESERVOIR

Designation of hydrograph	Volume of runoff (inches)*	Maximum instantaneous peak inflow (c.f.s.)	Maximum peak inflow per sq. mi. (c.f.s.)	Maximum peak inflow ÷ √D.A.	Percent of basic provisional spillway flood peak
A (Basin provisional spillway flood)	15.19	109,400	120	3,385	100.0
B	15.19	125,200	137	4,139	114.4
C	15.19	139,500	152	4,612	127.5

*Includes 0.54 inch base flow

31. RESULTS OF ROUTING SPILLWAY FLOODS.

Assuming the reservoir water surface at initial pool elevation 629.0 (spillway crest), spillway floods A, 1.25A, 1.5A, B and C were routed through the combined works of conduit and spillway. All inflow less than 3,980 c.f.s. was released through the conduit by gate regulation. When inflow exceeds 3,980 c.f.s. which is the conduit's discharge capacity at pool elevation 629.0 with gates wide open, the remainder of the flood is routed on an uncontrolled basis to a peak reservoir stage. Discharge rating curves for conduit and spillway are shown on plates D-7 and D-10 respectively. Plate D-11 shows reservoir elevation-inflow-outflow curves, resulting from flow routings in terms of basic provisional spillway flood volume or peak (hydrograph A). Points on curve P were computed by routing hypothetical hydrographs representing the same volume as the basic provisional spillway flood, but with higher peak rates and greater concentration of runoff. The quantitative effect of possible errors in estimating the critical regimen of runoff from the probable maximum storm are determined from curve P. In contrast, curve V was computed by routing hypothetical hydrographs representing a direct percentage increase in all ordinates of the basic provisional spillway flood hydrograph. The percentage increase in hydrograph ordinates is equivalent to an increase in volume of the design-storm rainfall-excess quantities without change in the assumed regimen of runoff as reflected by the unit hydrograph used in developing the basic provisional spillway flood estimate. A comparison of the slopes of curves P and V then becomes an index to the relative effects of possible errors in estimating the critical volume and regimen of runoff.

32. SPILLWAY DESIGN FLOOD.

After giving proper consideration to the results of procedures outlined in paragraphs 25 to 31, inclusive, with due regard for the elements of safety inherent in many of the end results, it was decided to adopt hydrograph B as the spillway design flood. Starting with reservoir pool elevation 629.0, the spillway flood, having peak inflow of 125,200 c.f.s., was routed through the combined works of spillway and conduit (gates operative) and attained maximum pool elevation 643.1 with a corresponding discharge of 14,450 c.f.s. from spillway and 4,200 c.f.s. from conduit. Inflow-outflow-pool stage hydrographs are shown on plate D-12. The spillway design flood produced a water surface elevation 0.21 foot higher than that of hydrograph A and 0.12 foot lower than that of hydrograph C.

33. FREEBOARD AND ELEVATION OF TOP OF DAM.

Freeboard was computed in accordance with procedures outlined in paper 3138, Journal of the Waterways and Harbors Division, A.S.C.E., Vol. 88, No. WW2, May 1962. Wind data for a representative first order U. S. Weather Bureau station shows a maximum velocity of record, expressed in miles per hour, for an approximate one minute duration, as follows:

Station	Velocity (m.p.h.)	Wind direction	Date	Years of record
Terre Haute	66	W	March 1948	41

It was estimated that for a given critical duration (time required for generation of wave heights) of 19 minutes a sustained velocity of 60 miles per hour overland obtains based on an effective fetch of 1.5 miles. Application of the above data as it pertains to riprapped embankment having a slope of 1 vertical to 2.5 horizontal, resulted in an estimate of 3.97 feet of run-up plus less than 0.2 foot of windtide. A freeboard of 5.0 feet, however, is the minimum allowable in the determination of embankment height. The adoption of elevation 648.0 as top of dam provides a freeboard of 5.00 feet.

34. NATURAL DISCHARGE - FREQUENCY CURVE AT HYPOTHETICAL GAGE.

A study of flow for given frequencies at a hypothetical gage, mile 79.9 on the Embarrass River, indicated that a sound discharge relationship between flow at that point and that at Ste. Marie should be determined by at least two different approaches. The two areas under study were transposed into nearly adjacent areas in Indiana. Using procedures, as outlined in U. S. G. S. publication "Floods in Indiana, Magnitude and Frequency," the two areas were found to be related as approximately the square root of the drainage areas. The second method was the actual application of the square root of the drainage area ratio to the Ste. Marie flow-frequency curve, plate D-13. The final flow-frequency curve adopted is an arithmetic average, of the two procedures outlined as above.

35. NATURAL STAGE - FREQUENCY CURVES.

The natural flow-frequency for the Ste. Marie and Mt. Carmel, Illinois, gages was based on reference entitled "Hydrologic Frequency Estimates, ER 1110-2-1450, 10 October 1962." For each station the frequent portion of the flow-frequency curve (500 to 50 events per 100 years) was based on peak flows of a partial duration series. In the rare portion of the frequency curve (10 to 0.1 events per 100 years) the curve was based on peak flows of annual flood series. The standard deviation was adjusted by annual flood volume series studies including durations 1, 3, 10, and 30-days. A skew coefficient equal to zero was assumed since the frequency curve is based on peak flows. Between exceedence frequencies of 50 and 10 per 100 years a logical transition curve was drawn. The resultant flow-frequency curve for Ste. Marie, Illinois, is shown on plate D-13. The natural stage-frequency curves were determined by application of the discharge rating curves to the flow-frequency curves. A discharge rating curve for the hypothetical gage was determined from flowline computations developed in the vicinity of mile 79.9. Stage-frequency curves on the Ohio River at Lock and Dam 50 and Paducah, Kentucky, used in evaluating flood damages, were developed by the Ohio River Division. The natural stage-frequency curves are shown on plates D-14 through D-18.

36. MODIFIED STAGE - FREQUENCY CURVES.

Modified frequency curves were determined by applying the reservoir holdouts of fourteen representative floods to the respective natural hydrographs or natural hydrographs modified by Group "A" reservoirs. The Lincoln dam site holdouts which were determined by routing the floods according to the reservoir regulation plan, were routed downstream in order to determine reductions and modified flows at the downstream damage gages. The peak modified flows of each flood at the respective damage control station was converted to stage by use of discharge rating curves. The peak modified stage for each of the floods was plotted under the peak natural curve or peak natural curve modified by Group "A" reservoirs for the same frequency. A smooth weighted curve drawn through the modified peak stages gives the modified stage-frequency curves. The modified stage-frequency curves are shown on plates D-14 through D-18.

SECTION III - CLIFTY CREEK RESERVOIR

37. GENERAL. The dam of Clifty Creek Reservoir is located 18.4 miles above the mouth of Clifty Creek, a tributary of the East Fork White River and about one mile southwest of Hartsville, Indiana. Upstream of the damsite lies an area of 139.8 square miles that comprises about one-half on one percent of the Wabash River Basin. The reservoir control of the drainage area above the damage point of Mt. Carmel, Illinois, is increased from 10.5 percent to 11.0 percent by the addition of Clifty Creek Reservoir over that of the total of Huntington Reservoir (advance planning), Salamonie Reservoir, Mississinewa Reservoir (each under construction), Mansfield Reservoir, Cagles Mill Reservoir, and Monroe Reservoir (under construction).

38. FLOW AT DAM SITE. Flows for flood periods earlier than February 1948 were established by application of effective rainfall to the dam site unit hydrograph. Flows later than February 1948 were determined by application of drainage area ratio 139.8/88.8 to the discharge of the Clifty Creek gaging station at Hartsville, Indiana.

39. UNIT HYDROGRAPH OF CLIFTY CREEK AT HARTSVILLE, INDIANA. The gaging station on Clifty Creek at Hartsville, established in February 1948, has a drainage area of 88.8 square miles and is situated about 2 miles upstream from the proposed site of Clifty Creek dam. Runoff derived by use of the data of this station provides an excellent measure of reservoir inflow due to the nearness of the gaging station and dam site. A study of gage records indicated three unit hydrographs of 6-hour duration of rainfall-excess which have similar characteristics. The three unit hydrographs, when averaged, produced a resultant unit graph that defines the regimen of runoff at the gaging point. The unit hydrographs are shown on plate D-19. Snyder's empirical unit hydrograph coefficients, based on the average unit graph of Clifty Creek at Hartsville are as follows:

Factor symbol

L (miles) = 31.0, L_{ca} (miles) = 19.0, $(LL_{ca})^{0.3}$ = 6.8

t_R (hours) = 6, t_{pR} (hours) = 16.5, Time of peak (hours) = 19.5

$C_t = \frac{t_{pR}}{(LL_{ca})^{0.3}} = 2.40$

q_{pR}(c.f.s./sq.mi.) = 29.3, Q_{pR} (c.f.s.) = 2,600

$C_p640 = 480$ $C_p = 0.750$

W_{50} (hours) = 18.8 W_{75} (hours) = 14.6

T (hours) = 108

40. UNIT HYDROGRAPH AT DAM SITE. Due to the proximity of the dam site to the gaging station on Clifty Creek at Hartsville, Indiana, the determination of a unit graph at the proposed site was accomplished through the application of drainage area ratio 139.8/88.8 to the unit graph at the gaging station. The resultant 6-hour unit hydrograph of Clifty Creek at the dam site is presented on plate D-20.

41. TAILWATER RATING CURVE. The tailwater curve for the dam was evaluated as the elevation-discharge values determined from computed profiles at mile 18.4. Coefficients of roughness varying from 0.050 to 0.052 in the channel and from 0.065 to 0.073 in the overbank were determined by reproducing the observed January 1959 flood profile from the mouth of Clifty Creek to the Hartsville gage at mile 20.3. The elevations of water surface for the various computed profiles were made consistent with the elevation-discharge relationship of the Hartsville gage. The elevation-discharge relationship thus developed at mile 18.4 was extended above 14,200 cubic feet per second by slope-area computations using Manning's formula. Plate D-21 shows the tailwater rating curve.

42. CHANNEL CAPACITY. Based on a study of the 18.4 miles of Clifty Creek below the Dam site, it is estimated that a flow of about 700 cubic feet per second can be carried by the stream without sustaining appreciable damage in the flood plain.

43. AREA AND CAPACITY OF RESERVOIR. Topographic quadrangle maps prepared by U. S. Geological Survey were used for determining pool areas and reservoir capacity. The maps have a scale of 1:24,000 and contour interval of 10 feet. The volume of reservoir capacity shown in table 11 was computed by this office using planimetered horizontal areas. Areas are given in acres and capacities in acre-feet and inches on drainage area. The capacity in inches runoff from the drainage area is based on an area of 139.8 square miles.

44. MINIMUM POOL. In order to meet the requirements of recreation, fish and wildlife and siltation, minimum pool is established at elevation 705, a level that provides an area of 550 acres and a volume of 7,700 acre-feet, which is equivalent to 1.03 inches runoff from the drainage area. Sedimentation records indicate a loss of about 70 acre-feet of storage annually, which when accumulated over a period of approximately 110 years would fill the reservoir pool to elevation 705.0. The annual loss represents about 0.9 percent of the minimum pool storage capacity.

TABLE 11
AREA AND CAPACITY
CLIFTY CREEK RESERVOIR,
CLIFTY CREEK, INDIANA
Mile 18.4

Elev. (ft. m.s.l.)	Area (acres)	Storage Capacity (acre-feet)	Storage Capacity (inches on drainage area)	Elev. (ft. m.s.l.)	Area (acres)	Storage Capacity (acre-feet)	Storage Capacity (inches on drainage area)
661	0	0	0	710	661	10,725	1.44
670	16	72	.0097	712	708	12,094	1.62
672	21	109	.0146	714	755	13,557	1.82
674	35	165	.0221	716	810	15,122	2.03
676	52	252	.034	718	860	16,792	2.25
678	68	372	.050	720	919	18,571	2.49
680	84	524	.070	722	982	20.472	2.75
682	105	713	.096	724	1050	22,504	3.02
684	128	946	.13	726	1126	24,680	3.31
686	155	1229	.16	728	1205	27,011	3.62
688	184	1568	.21	730	1290	29,506	3.96
690	212	1964	.26	732	1400	32,196	4.32
692	260	2436	.33	734	1515	35,111	4.71
694	305	3001	.40	736	1645	38,271	5.13
696	350	3656	.49	738	1785	41,701	5.59
698	390	4396	.59	740	1944	45,430	6.09
700	446	5232	.70	742	2105	49,479	6.64
702	480	6158	.83	744	2290	53,874	7.23
704	525	7163	.96	746	2490	58,654	7.87
706	570	8258	1.11	748	2710	63,854	8.56
708	618	9446	1.27	750	2944	69,508	9.32

45. RESERVOIR STORAGE FOR FLOOD CONTROL. The location of the town of Hartsville, Indiana, which is about 2 miles upstream from Clifty Creek dam, limits the maximum flood control pool (top of spillway gates) to elevation 745.0 and the induced surcharge pool to elevation 748.0. The total storage available at pool elevation 745.0 is 56,260 acre-feet which is equal to 7.55 inches runoff. The flood control storage below pool elevation 745.0 and above top of minimum pool (elevation 705.0) is 48,560 acre-feet which is equivalent to runoff of 6.51 inches.

46. RESERVOIR REGULATION PLAN. The regulation table, which gives allowable releases to meet flood control requirements downstream from Clifty Creek Reservoir, is based on critical channel capacities of 975 c.f.s. at mile 7.90 on Clifty Creek, and 2,500 c.f.s. at mile 231.5, East Fork White River. Flow from the uncontrolled drainage areas upstream from the critical damage points was determined by drainage area proportion of its areas to that of the area of the Columbus gage. The allowable reservoir releases indicated in the regulation table are the difference between critical channel capacity

and the flow from the uncontrolled area. The reservoir regulation table, which is based on natural flows at Columbus and which is a part of table 12, was developed for use of the study only. In addition, reservoir regulation is based on river conditions at damage centers at Bedford, Newberry, Mt. Carmel and Evansville. Controlling stages at the U. S. Weather Bureau gage at Bedford are 14 feet on a rising river and 26 feet on a falling river. Controlling stages at the U. S. Weather Bureau gage, Newberry, are 8 feet on a rising river and 18 feet on a falling river. Controlling stages at U. S. Weather Bureau gage at Mt. Carmel are 12 feet on a rising river and 23 feet on a falling river. Controlling stages at the U. S. Weather Bureau gage at Evansville are 35 feet on a rising river and 45 feet on a falling river. The controlling stages are based on the beginning of damage for reaches of the streams represented by the gages with due allowances for time of travel from Clifty Creek Reservoir to these damage points. When flood control pool elevation 745.0 is reached, the induced surcharge envelope curve will be followed up to elevation 748.0, which will be accomplished by gate regulation. If maximum induced surcharge elevation 748.0 is reached, the gates will be raised at a rate that will prevent further surcharging of the reservoir pool. When the modified peak inflow has been passed, the maximum gate opening will be held until reservoir pool recedes to elevation 745.0. All inflow will be passed until downstream controls permit drawdown of the flood control pool. Table 12, "Schedule of Regulation, Clifty Creek Reservoir," gives the details of procedure for regulation of the reservoir for flood control.

TABLE 12

CLIFTY CREEK RESERVOIR

SCHEDULE OF REGULATION

FLOOD CONTROL ONLY

Schedule	Controlling Stages (feet) E.F. White R. Bedford	White River Newberry	Wabash River Mt. Carmel	Ohio River Evansville	Range in Pool Elevation (feet)	Regulation
	(All stages must exist for application of Schedule A & B)					
A	Below 14R or Below 26F	Below 8R or Below 18F	Below 12R or Below 23F	Below 35R or Below 45F	Permanent Pool Elev. 705	Release inflow necessary to maintain pool provided allowable release indicated in Allowable Release Table is not exceeded.
B	Below 14R or Below 26F	Below 8R or Below 18F	Below 12R or Below 23F	Below 35R or Below 45F	705 - 745 **	Discharge allowable release indicated in Allowable Release Table.
	(Any one condition to exist for application of Schedule C)					
C	Above 14R or Above 26F	Above 8R or Above 18F	Above 12R or Above 23F	Above 35R or Above 45F	705 - 745 **	Release at constant rate of 300 c.f.s.
D	Controlling Stages not a factor				745 - 748 ***	Release inflow necessary to maintain the induced surcharge envelope curve elevation. After peak inflow has been reached, retain gate opening until pool returns to elevation 745.0 and then release all inflow through sluice and/or spillway gates thus maintaining pool elevation 745 until controlling stages allow emptying reservoir.

REGULATION TABLE

Natural Columbus Flow (c.f.s.)	Allowable Release (c.f.s.)
1590 & Under	700*
1590 - 1680	600
1680 - 1770	500
1770 - 1860	400
Over 1860	300

* Max. Release - 700 c.f.s.
** Max. Flood Control Pool
*** Max. Induced Surcharge Pool

Notes: Spillway contains 3-40 foot wide openings
Spillway Crest 717.0

47. UTILIZATION OF FLOOD CONTROL STORAGE. Regulation of the reservoir so as to store excess runoff of seven typical flood periods extending from 1933 through 1961, indicated that the highest reservoir pool stages attained were elevation 745.5 and 745.6 which occurred during the January 1937 and January through April 1950 flood periods, respectively. These reservoir pool elevations respectively, represent 102.4 and 103.2 percent utilization of flood control storage. Table 13 shows results of the reservoir regulation studies.

48. STANDARD PROJECT STORM. The Standard Project Storm, determined by the method outlined in Civil Engineering Bulletin No. 52-8, Corps of Engineers, dated March 26, 1952, is shown by 6-hour rainfall amounts in table 14. The standard project storm isohyetal pattern was superimposed over the Clifty Creek Reservoir drainage basin to obtain maximum rainfall, as shown on plate D-22. To obtain the rainfall-excess amounts, the storm was modified by an initial loss of 0.15 inch and an infiltration rate of 0.05 inch per hour. The infiltration and rainfall-excess amounts are also shown on table 14.

49. STANDARD PROJECT FLOOD. The Standard Project Storm rainfall-excess was applied to the Clifty Creek natural unit hydrograph on plate D-23, and an assumed base flow of 150 cubic feet per second was added. The resulting hydrograph was routed through the reservoir in accordance with the schedule of regulation presented in table 12, assuming the reservoir at minimum pool elevation 705.0 and the downstream control stations all above flood stage at the start of the Standard Project Storm. Outflow was regulated to maintain a minimum release of 300 cubic feet per second until maximum flood pool elevation 745.0 was attained. Above elevation 745.0 surcharge routing developed a maximum water surface elevation of 746.6. The Standard Project Flood was routed down to flood control pool 745.0 and all inflow will be passed through the sluiceway and/or spillway until downstream conditions indicate that the flood is over and that the reservoir can be emptied of its storage.

TABLE 13
FLOOD CONTROL STORAGE UTILIZATION DATA
CLIFTY CREEK RESERVOIR

Storage period		Accumulated storage above minimum pool (ac. ft.) *	Percent of storage utilization **	Maximum reservoir pool elev. (ft.m.s.l.)	Peak reservoir inflow (c.f.s.)	Peak reservoir outflow (c.f.s.)
Flood date	Date of maximum stage					
May 1933	May 28	29,580	60.9	735.4	8,900	300
January 1937	Jan. 22	49,720	102.4	745.5	9,000	4,400
March 1939	Mar. 14	19,040	39.2	727.8	6,600	300
January-April 1950	Feb 14	50,094	103.2	745.6	10,300	6,600
May 1957	May 25	17,440	35.9	726.5	6,400	300
Jan.-Feb. 1959	Feb. 19	33,900	69.8	738.0	11,300	600
May 1961	May 12	25,880	53.3	733.0	6,120	300

* Minimum Pool elevation 705.0
** Flood Control Storage at full reservoir (elevation 745.0) is 48,560 acre-feet

TABLE 14
STANDARD PROJECT STORM
RAINFALL AND RAINFALL-EXCESS
ABOVE CLIFTY CREEK DAM SITE

Time in hours	6-Hour rainfall (inches)	Infiltration loss (inches)	Rainfall excess (inches)
0-6	0.03	0.03	0
6-12	0.09	0.09	.10
12-18	0.43	0.30	0.13
18-24	0.05	0.05	0
24-30	0.10	0.10	0
30-36	0.28	0.28	0
36-42	1.44	0.30	1.14
42-48	0.18	0.18	0
48-54	0.63	0.30	0.33
54-60	1.76	0.30	1.46
60-66	9.08	0.30	8.78
66-72	1.13	0.30	0.83
72-78	0.01	0.01	0
78-84	0.04	0.04	0
84-90	0.22	0.22	0
90-96	0.03	0.03	0
TOTAL	15.50	2.83	12.67

50. SEASONAL POOL REGULATION PLAN. Seasonal low flow regulation is predicated on reducing the allocated flood control storage during the summer months and, thereby, increase the water surface in the interest of general recreation and make available storage for increasing the natural flow between 1 April and 30 November. The method is as follows: Starting 1 April with pool at minimum level the water surface in the reservoir would be raised as rapidly as inflows will permit so as to attain the seasonal pool elevation by 1 May. The seasonal pool elevation is set at such a level that it will be attained three-fourths or more of the years. With pool elevations at or near seasonal level, storage can be released when necessary to satisfy minimum flow objectives downstream. The Fish and Wildlife Service in Appendix F, exhibit F-3 stated that in order to sustain the estimated number of anglers downstream from the dam, it would require minimum discharges of at least 20 cubic feet per second. Such flow objective would result in substantial lowering of the seasonal pool during the recreation season. Accordingly, more detailed studies should be made during the advanced planning period of the reservoir project in order to ascertain a realistic minimum reservoir release consistent with existing conditions. Seasonal pool level for Clifty Creek Reservoir was set at elevation 720.0 which provides 10,870 acre-feet or 1.46 inches runoff of storage above the top of minimum pool (elevation 705.0). Beginning 1 September and ending 30 November the pool would be depleted while meeting low flow and flood control requirements so as to be down to minimum pool at the end of November. The water surface increases from an area of 550 acres at minimum pool level to 919 acres at seasonal pool level.

51. SPILLWAY. A concrete overflow section through the dam embankment and founded on rock is proposed as the spillway. The spillway consists

of three 40-foot wide openings with the spillway section having an ogee shape and crest at elevation 717.0. Two 10-foot wide piers are spaced so as to accommodate three 28-foot high by 40-foot wide tainter gates. Discharge rating of the three spillway openings was developed through use of the basic weir formula:

$$Q = CLH^{3/2}$$ where:

Q = discharge, in cubic feet per second
C = discharge coefficient
H = head on ogee crest, in feet
L = effective length of spillway, in feet
$L = L' - 2\,(NK_p + K_a)\,H$
L' = net length of spillway, in feet
N = number of piers
K_p = pier contraction coefficient
K_a = abutment contraction coefficient

Values of C, K_p and K_a were determined from plates 5, 13 and 14, respectively, of Engineering Manual titled "Hydraulic Design, Spillways." Discharge capacity of the three 40-foot openings at top flood control elevation 745.0, is about 71,700 cubic feet per second. Spillway discharge rating curve is shown on plate D-24.

52. STILLING BASIN. The stilling basin is designed on the basis of a reservoir outflow of 71,000 cubic feet per second. The corresponding pool elevation for 71,000 cubic feet per second is 744.8, which is 27.8 feet above top of spillway crest elevation 717.0. Details of the stilling basin are shown on plates D-25 and D-26. The tailwater level corresponding to a flow of 71,000 cubic feet per second is estimated to be at elevation 695.2. The jump-height, to satisfy the momentum equation, based on a stilling basin width of 140-feet and a floor elevation 653.9, is computed to be at elevation 695.2. Assurance that the hydraulic-jump will occur in the basin is afforded by a jump-height computation made at the upstream end of the end sill in which reduction in D_2 of 10 percent is made for head losses resulting from floor, walls, baffle blocks and end sill. The jump-height thus computed (41.3) feet will rise to the tailwater level for 71,000 cubic feet per second. The length of the stilling basin was established at 124 feet, which is about 3.0 times the design jump-height (41.3 feet). The maximum velocity in the channel immediately downstream from the end sill, for flows up to 71,000 cubic feet per second, is estimated to be less than 15 feet per second. To prevent erosion in the channel, riprap will be placed for approximately 100 feet downstream from the end sill.

53. RESERVOIR OUTLETS. Since Clifty Creek Reservoir will have a concrete spillway, sluices are built into the concrete structure. Two 4-foot wide by 6-foot high passageways with entrance invert at elevation 666.0 are provided. A bellmouth entrance is provided in order to eliminate negative pressures in localized areas at the entrance of the sluiceway. Heavy trash bars are stipulated at the

entrance of each sluiceway. The total length of each sluiceway is about 70 feet. In order to provide for flexible regulation of outflows, each passageway will be provided with a gate capable of restricting the opening (part gate). Additional details of sluices are given on plate 5 of report. The two sluices will discharge 1,960 cubic feet per second at minimum pool elevation 705.0 and 2,860 cubic feet per second at maximum flood control pool elevation 745.0. Plate D-27 gives the discharge rating of the two sluices assuming all gates are wide open.

54. SELECTION OF PROBABLE MAXIMUM STORM. The basis of season variations of the probable maximum rainfall are shown in paragraph 4 and depth values are given in table 1. The seasonal storm selection for spillway design is that storm runoff which when routed through the spillway will produce the maximum reservoir pool stage. The reservoir pool elevation at the beginning of the spillway design flood is the maximum pool for the same season obtained from routings made according to the Reservoir Regulation Plan, the results of the routings are shown in table 13. The April seasonal storm produced a peak runoff at the dam site of 71,000 c.f.s. (spillway design flood) and the highest initial pool, that at elevation 745.0, obtained 4-7 April 1950. The discharge capacity of 3-40 foot wide spillway openings is estimated at 71,700 c.f.s. and the 2-4 foot by 6 foot sluices at 2,600 c.f.s. The spillway design flood will be routed through the spillway utilizing the 3 feet of induced surcharge storage between pool elevations 745.0 and 748.0. Table 13 indicates that the maximum reservoir pool likely to be obtained in the month of May as that of elevation 735.4, obtained 28 May 1933. Thus the initial pool for the May seasonal storm which is estimated to have a peak runoff of about 80,000 c.f.s. is 9.6 feet lower than the initial pool for April. Since the peak of the May seasonal flood is only about 7 percent larger than the combined capacity of the spillway and sluices (74,300 c.f.s.) at pool elevation 745, and in view of the lower starting pool elevation that spillway routings would have in May, the April seasonal probable maximum flood is adopted as the basis of spillway design.

55. RUNOFF OF PROBABLE MAXIMUM STORM. Based on studies of infiltration during late spring and summer, a minimum rate of 0.05 inch per hour was selected. Initial loss was assumed to be 0.15 inch. Six-hour ordinates of the April probable maximum storm were arranged in the sequence which would produce maximum peak discharge in the design flood hydrograph. Table 15 shows the distribution of rainfall, infiltration and rainfall-excess by 6-hour periods.

TABLE 15
PROBABLE MAXIMUM DISTRIBUTION
FOR SPILLWAY DESIGN FLOOD
CLIFTY CREEK
RESERVOIR
APRIL STORM

Time in hours	6-Hour rainfall (inches)	Infiltration loss (inches)	Rainfall excess (inches)
0-6	0.60	0.38	0.22
6-12	0.70	0.30	0.40
12-18	0.80	0.30	0.50
18-24	0.90	0.30	0.60
24-30	1.10	0.30	0.80
30-36	3.30	0.30	3.00
36-42	8.80	0.30	8.50
42-48	0.80	0.30	0.50
Total	17.00	2.48	14.52

56. INFLOW UNIT HYDROGRAPHS. The inflow unit hydrographs developed for spillway design were based on an average pool level above elevation 745.0, which is believed to provide sequence of inflow likely to occur during the spillway floods. The reservoir drainage area was subdivided into the following areas:

a. Three areas above head of reservoir totaling 121.4 square miles.

b. Four areas adjacent to the reservoir surface totaling 15.36 square miles.

c. Reservoir surface area, 3.04 square miles.

Regimen of flood runoff is defined by inflow unit hydrographs developed for runoff originating above head of the reservoir pool and for runoff contributing to the pool from individual areas along its periphery. Time required by flood waters entering the upper end of the reservoir to become effective in raising the reservoir level at the dam and spillway sites was investigated and found to be less than one hour.

57. UNIT HYDROGRAPHS FOR BASIN ABOVE HEAD OF RESERVOIR. The area above the head of the reservoir, 121.4 square miles, was divided into three sub-areas designated 1-a, representing drainage from 78.65 square miles of Clifty Creek, 1-b, representing drainage from 9.59 square miles of Middle Fork, a tributary of Clifty Creek and 1-c, representing drainage from 33.16 square miles of Fall Fork, a tributary of Clifty Creek. Area 1-a unit graph was developed by drainage area proportion using the Hartsville unit graph. Unit graphs for areas 1-b and 1-c were developed by the use of Snyder's method. Snyder coefficients, other than those measured for L and L_{ca} were derived

through the correlation of data from other areas which have similar runoff characteristics. The coefficients C_t and C_p , thus derived, together with the coefficients $(LL_{ca})^{0.3}$, which were used in the evaluation of other coefficients such as "Lag" time, hydrograph widths (hours) at 50 and 75 percent of peak discharge, are shown in table 16. Through use of the above mentioned coefficients, basic unit graphs for the individual areas designated 1-b and 1-c were developed by adopting patterns most consistent with corresponding S-curve hydrographs as shown in table 16. Unit hydrographs 1-a, 1-b and 1-c were then combined to produce the total inflow unit hydrograph 1-A for the entire 121.4 square mile area at the head of the reservoir. Since storms of a magnitude approaching the probable maximum produce peak discharges of the unit hydrograph that are consistently higher than those computed from records of minor floods, the peak of hydrograph 1-A was increased arbitrarily by 25 and 50 percent. Thus, hydrographs 1-B and 1-C each having the same volume as hydrograph 1-a but of different degrees of concentration for the total area at the head of Clifty Creek Reservoir, were developed. Pertinent unit hydrograph data relative to the sub-area, including 3-hour instantaneous values of unit and S-curve hydrographs are shown in table 17.

TABLE 16

BASIC UNIT AND S-CURVE HYDROGRAPHS FOR
HEAD OF RESERVOIR SUB-AREAS
CLIFTY CREEK RESERVOIR, CLIFTY CREEK, INDIANA

Location: Sub-area 1a

Drainage area = 78.65 sq. mi.
t_R = 6 hours
Snyder's Equations:
C_t = 2.4
C_p = .75
L = 23.0 miles
L_{ca} = 13.0 miles
$(LL_{ca})^{0.3}$ = 6.7
S-Curve
$Q_{MAX} = \text{(drainage area)}\ (26.889)\ \frac{(24)}{(t_R)}$
= 8,459 c.f.s.
q_{PR} = 29.8 c.f.s./sq.mi.
Lag(t_{PR}) = 16.1 hrs.
W_{75} = 14.5 hrs. W_{50} = 17.5 hrs.
T = 108 hrs.

Location Sub-area 1b

Drainage area = 9.59 sq. mi.
t_R= 6 hours
Snyder's Equations:
C_t= 0.93
C_p= 0.55
L = 9.9 miles
L_{ca}= 5.2 miles
$(LL_{ca})^{0.3}$ = 3.7
S-Curve
$Q_{MAX} = \text{(drainage area)}\ (26.889)\ \frac{(24)}{(t_R)}$
= 1,032 c.f.s.
q_{PR} = 85.4 c.f.s./sq. mi.
Lag(t_{PR}) = 4.1 hrs.
W_{75} = 4.5 hrs. W_{50} = 6.3 hrs.
T = 36 hrs.

Location Sub-area 1c

Drainage area = 33.16 sq. mi.
t_R = 6 hours
Snyder's Equations:
C_t = 2.2
C_p = 0.75
L = 14.0 miles
L_{ca} = 6.4 miles
$(LL_{ca})^{0.3}$ = 3.9
S-Curve
$Q_{MAX} = \text{(drainage area)}\ (26.889)\ \frac{(24)}{(t_R)}$
= 3,565 c.f.s.
q_{PR} = 57.5 c.f.s./sq. mi.
Lag (t_{PR}) = 8.4 hrs.
W_{75} = 6.1 hrs. W_{50}= 9.5 hrs.
T = 39 hrs.

Time in hours	1a Unit hydrograph (c.f.s.)	1a S-Curve hydrograph (c.f.s.)	1b Unit hydrograph (c.f.s.)	1b S-Curve hydrograph (c.f.s.)	1c Unit hydrograph (c.f.s.)	1c S-Curve hydrograph (c.f.s.)
0	0	0	0	0	0	0
3	180	180	120	120	168	168
6	790	790	750	750	708	708
9	1718	1898	755	875	1629	1797
12	1820	2610	180	930	1876	2584
15	1972	3870	95	970	1266	3063
18	2340	4950	60	990	698	3282

TABLE 16 (Cont'd)

Time in Hours	Location Sub-area 1a Unit hydrograph (c.f.s.)	Location Sub-area 1a S-curve hydrograph (c.f.s.)	Location Sub-area 1b Unit hydrograph (c.f.s.)	Location Sub-area 1b S-curve hydrograph (c.f.s.)	Location Sub-area 1c Unit hydrograph (c.f.s.)	Location Sub-area 1c S-curve hydrograph (c.f.s.)
21	2337	6207	38	1008	340	3403
24	1630	6580	30	1020	200	3482
27	643	6850	20	1028	126	3529
30	480	7060	12	1032	74	3556
33	380	7230	4	1032	36	3565
36	300	7360	0	1032	9	3565
39	260	7490			0	3565
42	220	7580				
45	180	7670				
48	173	7753				
51	159	7829				
54	149	7902				
57	133	7962				
60	121	8023				
63	106	8068				
66	98	8121				
69	89	8157				
72	81	8202				
75	71	8228				
78	69	8271				
81	65	8293				
84	59	8330				
87	55	8348				
90	51	8381				
93	47	8395				
96	43	8424				
99	39	8434				
102	35	8459				
105	31	8459				
108	0	8459				

TABLE 17
UNIT AND S-CURVE HYDROGRAPHS
FOR HEAD OF RESERVOIR TOTAL AREA
CLIFTY CREEK RESERVOIR, CLIFTY CREEK, INDIANA

Location: Sub-area 1, drainage area 121.4 sq. mi. t_R = 6 hrs.
Snyder's equations: (separate determination for each sub-area)
S-Curve: $Q_{MAX} = (\text{drainage area})(26.889)\left(\frac{24}{t_R}\right) = 13{,}057$ c.f.s.

	GRAPH 1-A	GRAPH 1-B	GRAPH 1-C
q_{PR}	= 33.79 c.f.s./sq. mi.	= 42.24 c.f.s./sq. mi.	= 50.68 c.f.s./sq. mi.
t_R	= 6 hrs.	= 6 hrs.	= 6 hrs.
Lag (t_{PR})	= 6.0 hrs.	= 5.0 hrs.	= 4.5 hrs.
W_{75} / W_{50}	W_{75} = 12.0 hrs. W_{50} = 17.5 hrs.	W_{75} = 7.5 hrs. W_{50} = 11.6 hrs.	W_{75} = 5.5 hrs. W_{50} = 8.5 hrs.
T	= 108 hrs.	= 102 hrs.	= 99 hrs.

Time in hours	1-A Unit hydrograph (c.f.s.)	1-A S-curve hydrograph (c.f.s.)	1-B Unit hydrograph (c.f.s.)	1-B S-curve hydrograph (c.f.s.)	1-C Unit hydrograph (c.f.s.)	1-C S-curve hydrograph (c.f.s.)
0	0	0	0	0	0	0
3	468	468	1395	1395	1428	1428
6	2248	2248	4413	4413	5361	5361
9	4102	4570	5100	6495	6045	7473
12	3876	6124	4280	8693	3350	8711
15	3333	7903	3200	9695	2130	9603
18	3098	9222	1540	10233	1520	10231
21	2715	10618	980	10675	1130	10733
24	1860	11082	785	11018	870	11101
27	789	11407	655	11325	710	11443
30	566	11648	560	11578	580	11681
33	420	11827	475	11800	450	11893

TABLE 17 (Cont'd)

Time in hours	GRAPH 1-A Unit hydrograph (c.f.s.)	GRAPH 1-A S-curve hydrograph (c.f.s.)	GRAPH 1-B Unit Hydrograph (c.f.s.)	GRAPH 1-B S-curve hydrograph (c.f.s.)	GRAPH 1-C Unit hydrograph (c.f.s.)	GRAPH 1-C S-curve hydrograph (c.f.s.)
36	308	11956	400	11978	380	12061
39	260	12087	340	12140	300	12193
42	220	12176	285	12263	250	12311
45	180	12267	235	12375	220	12413
48	173	12349	210	12473	200	12511
51	159	12426	190	12565	180	12593
54	146	12495	165	12638	160	12671
57	133	12559	145	12710	140	12733
60	120	12615	130	12768	120	12791
63	106	12665	110	12820	105	12838
66	97	12712	100	12868	90	12881
69	89	12754	85	12905	80	12918
72	80	12792	75	12943	66	12947
75	71	12825	65	12970	60	12978
78	69	12861	50	12993	50	12997
81	65	12890	40	13010	39	13017
84	59	12920	34	13027	33	13030
87	55	12945	27	13037	26	13043
90	51	12971	20	13047	19	13049
93	47	12992	15	13052	14	13057
96	45	13016	10	13057	8	13057
99	43	13035	5	13057	0	13057
102	41	13057	0	13057		
105	22	13057				
108	0	13057				

58. UNIT HYDROGRAPHS FOR AREAS ADJACENT TO RESERVOIR POOL. Area 2 was divided into four sub-areas aggregating to 15.36 square miles, the smallest of which is 1.78 and the largest 7.73 square miles. Unit hydrographs for these areas, lying along the periphrey of the reservoir pool, were developed by synthetic methods, due to the absence of observed flow records for each of the respective streams. Unit hydrograph values thus derived were for peak discharge, time of peak, the discharge at twice the time of peak and base time. These values were related to slope of the valley and the size of the drainage area for the condition of uniform distribution of rainfall. Ordinates of the four one-hour unit graphs were combined into a single one-hour unit graph and this converted into a unit hydrograph of 6-hour duration of rainfall-excess. The resultant unit hydrograph, designated 2, having peak flow of 1,464 c.f.s. or 95.3 c.f.s. per square mile of drainage area is shown in table 18.

TABLE 18
TOTAL UNIT HYDROGRAPH
FOR AREAS ADJACENT TO RESERVOIR POOL
CLIFTY CREEK RESERVOIR

Time in hours	Discharge (c.f.s.)	Time in hours	Discharge (c.f.s.)
0	0	12	160
	380		95
3	1042	15	47
	1360		20
6	1464	18	6
	1235		2
9	537	21	0
	260		

59. RUNOFF FOR RESERVOIR POOL AREA. Since the rate of runoff for the surface of the reservoir pool is equal to the rate of rainfall, one inch of rainfall in six hours over 3.04 square miles of pool area representa a uniform discharge of 327 c.f.s. from area 3. Accordingly, for a rainfall of 1-inch in 6 hours the following runoff results:

Time in hours	Discharge (c.f.s.)
0-3	327
3-6	327

60. SPILLWAY FLOODS. Since the volume and time and degree of concentration of runoff into the reservoir cannot be ascertained with a high order of accuracy, it is desirable to estimate the extent of

variations in maximum reservoir levels that would obtain from varied basic assumptions regarding runoff. By application of the "rainfall-excess" of table 15 to unit hydrographs 1-A and 2, plus the application of "rainfall" from the same table to unit graph 3, the basic provisional spillway flood, designated hydrograph A, was developed. Hydrographs of design storms that reflect greater concentrations of runoff than that indicated for the provisional spillway flood were developed through application of unit graphs 1-B and 1-C, respectively, to increments of rainfall-excess covering the 12-hour period of greatest intensity and substituted in proper time relation for the corresponding runoff computed by use of unit graph 1-A. Hydrographs A, B, and C shown in table 19 were developed by procedures outlined above. Comparative data, showing maximum reservoir inflow(59,000 c.f.s.)for the basic provisional spillway flood, peak flow for greater concentration of runoff, and other characteristics, are presented in Table 20.

TABLE 19
HYPOTHETICAL HYDROGRAPHS OF RUNOFF FROM SPILLWAY DESIGN STORM
CLIFTY CREEK RESERVOIR, CLIFTY CREEK, INDIANA

Time in hours	Inflow hydrograph 3-hr average values (c.f.s.)			Time in hours	Inflow hydrograph 3-hr average values (c.f.s.)		
	A*	B**	C		A*	B**	C
0-3	487	487	487	75-78	3145	3904	3616
3-6	1094	1094	1094	78-81	2744	3368	3100
6-9	1975	1975	1975	81-84	2419	2925	2805
9-12	2598	2598	2598	84-87	2252	2644	2535
12-15	3883	3883	3883	87-90	2073	2362	2270
15-18	5201	5201	5201	90-93	1896	2118	2023
18-21	9031	9031	9031	93-96	1746	1855	1788
21-23	8664	8664	8664	96-99	1596	1663	1566
23-27	7100	7100	7100	99-102	1456	1489	1403
27-30	7315	7315	7315	102-105	1353	1316	1233
30-33	10202	10916	11207	105-108	1233	1177	1114
33-36	14125	18484	20017	108-111	1131	1034	963
36-39	25795	31580	35417	111-114	1054	898	861
39-42	37648	52240	57590	114-117	995	738	727
42-45	56399	67935	72892	117-120	925	634	623
45-48	50183	55104	55266	120-123	855	541	529
48-51	43701	41056	31227	123-126	796	454	439
51-54	37666	29195	21936	126-129	739	367	350
54-57	30892	14959	16087	129-132	690	304	279
57-60	24250	11562	12711	132-135	630	234	208
60-63	13574	9701	10467	135-138	553	198	172
63-66	8428	8218	8394	138-141	427	172	172
66-69	6011	6592	6523	141-144	264	170	170
69-72	4627	5455	5161	144-147	165	165	165
72-75	3721	4632	4353	147-150	156	156	156

* Basic provisional spillway flood runoff
** Adopted as spillway design flood

TABLE 20
SPILLWAY FLOOD DATA
CLIFTY CREEK RESERVOIR

Designation of hydrograph	Volume of runoff (inches)*	Maximum instantaneous peak inflow (c.f.s.)	Maximum peak inflow per sq. mi. (c.f.s.)	Maximum peak inflow ÷ √D.A.	Percent of basic provisional spillway flood peak
A (Basic provisional spillway flood)	14.82	59,000	422	4,990	100.0
B	14.82	71,000	508	6,005	120.3
C	14.82	76,000	544	6,428	128.8

* Includes 0.25 inch base flow

61. RESULTS OF ROUTING SPILLWAY FLOODS. Using an initial pool at elevation 745.0 with the spillway gates operative, the spillway floods A, 1.25A, 1.50A, B, and C were routed through the reservoir. In the beginning of the flood routings, when outflow was less than 700 cubic feet per second, the channel capacity, there was no surcharging of the flood control pool elevation 745.0. When inflows increased above channel capacity, the induced surcharge envelope curve shown on plate D-24 was used to regulate the outflow and insure that maximum surcharge pool elevation 748.0 was not exceeded. After the floods had crested, the maximum gate openings were retained until the floods receded to static flood control pool elevation 745.0.

Discharge ratings for spillway and sluiceways are shown on plates D-24 and D-27, respectively. Reservoir elevation-inflow-outflow curves, which result from flow routings, in terms of basic provisional spillway flood volume or peak (hydrograph A) are presented in plate D-28. Points on curve P were computed by routing hypothetical hydrographs representing the same volume as the basic provisional spillway flood, but with higher peak rates and consequently greater concentration of runoff. The quantitative effect of possible errors in estimating the critical regimen of runoff from the probable maximum storm are determined from curve P. In contrast, curve V was computed by routing hypothetical hydrographs representing a uniform percentage increase in all ordinates of the basic provisional spillway flood hydrograph. The percentage increase in hydrograph ordinates is equivalent to an increase in volume of the design-storm-rainfall-excess quantities. There is no change in the assumed regimen of runoff as previously established by the unit hydrograph used in development of the basic provisional spillway flood estimate. The slopes of curves P and V when compared, serve as an index to the relative effects of possible errors in estimating the critical volume and regimen of runoff.

62. SPILLWAY DESIGN FLOOD. After due consideration was given the factors, as presented in foregoing paragraphs 54 through 61 together with the relative and inherent elements of safety involved, hydrograph B was adopted as the spillway design flood. Hydrograph B, with a peak discharge of 71,000 cubic feet per second, will surcharge static flood control pool elevation 745.0 to elevation 747.71, with a modified peak outflow of 63,200 cubic feet per second.

Hydrograph C with a peak discharge of 76,000 c.f.s. will surcharge static flood control pool elevation 745.0 to elevation 747.85 with a modified peak outflow of 68,000 cubic feet per second.

Hydrograph A, with its peak of 59,000 c.f.s. will also surcharge static flood control pool elevation 745.0 to elevation 747.23 with a modified peak outflow of 51,400 cubic feet per second.

63. FREEBOARD AND ELEVATION OF TOP OF DAM. Freeboard was computed in accordance with procedures outlined in paper 3138 Journal of the Waterways and Harbors Division, ASCE, Vol. 88, No. WW2, May 1962. Wind data for two representative first order U. S. Weather Bureau stations show maximum velocities of record, expressed in miles per hour, for an approximate one minute duration, as follows:

Station	Velocity (m.p.h.)	Wind Direction	Date	Years of record
Indianapolis	111	NW	June 1929	81
Louisville	68	NW	May 1915	51

It was estimated that for a given critical duration (time required for generation of wave heights) of 19 minutes, a sustained velocity of 60 miles per hour overland obtains based on an effective fetch of 1.5 miles. Application of the above data as it pertains to riprapped embankment having a slope of 1 vertical to 2.5 horizontal, resulted in an estimate of 3.9 feet of run-up plus less than 0.4 foot of wind-tide. A freeboard of 5.0 feet, however, is the minimum allowable in the determination of embankment height. The adoption of elevation 753.0 as top of dam provides a freeboard of 5.00 feet.

64. NATURAL STAGE - FREQUENCY CURVES.

The natural flow-frequency for Hartsville, Seymour, Shoals, and Petersburg, all in Indiana, were based on reference entitled "Hydrologic Frequency Estimates, ER 1110-2-1450, 10 October 1962." The same methods of evaluating flow-frequency for these stations are used as that for the Ste. Marie and Mt. Carmel, Illinois stations which are given in paragraph 35. The natural stage-frequency curves for Seymour, Shoals and Petersburg were determined by application of the discharge rating curves to the flow-frequency curves. The flow-frequency curve for Petersville, a hypothetical gage on Clifty Creek was determined by increasing the flows of the flow-frequency curve shown as plate D-30 by approximately the square root of the drainage area. A discharge rating curve determined from backwater computations on Clifty Creek was used to develop a stage-frequency curve at Petersville. The natural stage-frequency curves are shown on plates D-31 through D-35.

65. MODIFIED STAGE-FREQUENCY CURVES.

Modified frequency curves were determined by applying the reservoir holdouts of seven representative floods (May 1933, January 1937, March 1939, February 1950, May 1957, January 1959 and May 1961) to the respective natural hydrographs or natural hydrographs modified by Group "A" reservoirs. The modified stage-frequency curves downstream for Clifty Creek dam site were determined by similar methods to that indicated in paragraph 36. The modified stage-frequency curves are shown on plates D-31 through D-35.

SECTION IV - PATOKA RESERVOIR

66. GENERAL.

a. ACKNOWLEDGEMENT. The Indiana Flood Control and Water Resources Commission has developed the Patoka Reservoir project in "Survey Report for Flood Control and Water Resources Development, Patoka River Basin, Indiana, Appendix A - Hydrology, September 1962 and Appendix B - Ellsworth Reservoir Studies, January 1963." The dam and reservoir referred to as Ellsworth by I.F.C. & W.R.C. is the Patoka Reservoir of the Corps of Engineers. Where available the hydrology and hydraulic data, computations, and results, which had already been developed by that agency, were utilized in the present report. However, before this work was used it was reviewed by the Corps of Engineers. Special mention is made of the natural flow and stage frequency determinations on the Patoka River by the I.F.C. & W.R.C. which differs from the Corps of Engineers methods. The I.F.C. & W.R.C. frequency determinations were considered adequate for the purpose of this report (survey scope). It is to be emphasized that when advanced planning studies are made the flow-frequency curves on Patoka River should be revised according to ER 1110-2-1450 10 October 1962. The methods used by I.F.C. & W.R.C. in the frequency determination submitted in this report are given in paragraph 91.

b. DESCRIPTION. The dam of Patoka Reservoir is located on Patoka River, 118.3 miles above its mouth, 212.9 miles above the mouth of Wabash River, and about 0.7 mile northeast of Ellsworth in Dubois County, Indiana. The drainage area above the dam is 168 square miles or 0.5 percent of the area of the Wabash River Basin. The reservoir controls 64 percent of the drainage area above the damage point at Jasper, Indiana. The reservoir control of the drainage area above the damage point of Mt. Carmel, Illinois, is increased from 10.5 percent to 11.2 percent by the addition of Patoka Reservoir over that of the total of Huntington Reservoir (advance planning), Salamonie Reservoir, Mississinewa Reservoir (each under construction), Mansfield Reservoir, Cagles Mill Reservoir, and Monroe Reservoir (under construction).

67. FLOW AT DAM SITE.

Flow from January 1944 through September 1961 at the Patoka Reservoir dam site was established by application of drainage area proportion to discharge of the Patoka River station at Jasper, Indiana. For periods earlier than January 1944, flows at the dam site were determined by use of unit hydrograph.

68. UNIT HYDROGRAPH OF PATOKA RIVER AT JASPER, INDIANA.

The Patoka River gaging station at (Indiana State Highway No. 164 bridge) Jasper, Indiana, which was established in November 1947 and since September 1956 used as a supplementary gage, defines the regimen of natural runoff effective at a point 86 miles upstream from the mouth

of Patoka River, where the drainage area is 274 square miles. From basic data established at the gaging point, four unit hydrographs of 6-hour duration of rainfall-excess were developed. The unit hydrographs, together with the average 6-hour unit hydrograph (designated A) and adjusted developed unit hydrograph (designated B), are shown on plate D-36. Snyder's empirical unit hydrograph coefficients, based on average unit hydrograph (A) and adjusted developed unit hydrographs at the Patoka River gage at Jasper, are as follows:

Factor Symbol	Unit Graph A	Unit Graph B
L (miles)	78	78
L_{ca} (miles)	38	38
$(LL_{ca})^{0.3}$	11.0	11.0
t_R (hours)	6	6
t_pR (hours)	81	63

Factor Symbol	Unit Graph A	Unit Graph B
t_p (hours)	83	64
$C_t = \frac{t_pR}{(LL_{ca})\ 0.3}$	7.54	5.85
q_pR (c.f.s./sq.mi.)	6.02	7.66
Q_pR (c.f.s.)	1,650	2,100
C_p 640	488	483
C_p	0.762	0.755
W_{50}(hours)	98	69
W_{75} (hours)	57	42
T (hours)	234	246

69. UNIT HYDROGRAPH AT DAM SITE.

Because of the proximity of the dam site to the gaging station, Patoka River near Ellsworth, Indiana, the difference in drainage area is some 4 square miles. The dam site unit hydrograph was assumed to be the same as the Ellsworth unit hydrograph. The 6-hour unit hydrograph is shown on plate D-37.

70. TAILWATER RATING CURVES.

Tailwater curves for the outlet works at mile 118.0 and for the spillway at mile 118.0 were developed. By using data from a preliminary stage-discharge relation curve at the gage near Ellsworth and from three known water surface profiles and discharges, several other water surface profiles were developed in the reach from the Ellsworth gage to the dam site. The profiles, computed on electronic computer, were for flows ranging from low water to major floods and data therefrom was used in plotting the tailwater curves as shown on plate D-38.

71. CHANNEL CAPACITY.

Maximum controlled reservoir releases are based on a study of approximate capacity of existing channel of Patoka River at Jasper and at the Ellsworth gage some 2.2 miles below the dam site. Stage-damage and stage-discharge data at Jasper indicate that the discharge equivalent of flood stage under present conditions is about 2,400 cubic feet per second, and the preliminary stage-discharge relation for the Ellsworth gage indicates a bank-full capacity of approximately 1,500 cubic feet per second was adopted as the maximum allowable controlled reservoir release.

72. AREA AND CAPACITY OF RESERVOIR.

Area and capacity determinations for Patoka Reservoir is based on U. S. Geological Survey maps which have a scale of 1:24000 and contour interval of 10 feet. The volume of reservoir capacity shown in table 21 was determined by Indiana Flood Control and Water Resources Commission using planimetered horizontal areas, and accepted by this office. The capacity in inches runoff from the drainage area is based on an area of 168 square miles.

73. MINIMUM POOL.

Minimum pool was established at elevation 506.0 to satisfy the requirements of recreation, wildlife and siltation. Pool elevation 506 provided for an area of 2,010 acres, corresponding to a volume of 13,200 acre-feet, an equivalent of 1.47 inch runoff for the drainage area. Based on sedimentation records, it is estimated that about 100 acre-feet of storage will be lost annually, and, thus in about 130 years the storage presently available at pool elevation 506 will be filled by silt. The annual loss represents about 0.7 percent of the storage capacity available at minimum pool.

73a. WATER SUPPLY AND WATER QUALITY STORAGE.

A storage of 167,800 acre-feet between minimum pool elevation 506.0 and top of conservation pool elevation 536.0 at Patoka Reservoir is to be used to provide firm regulated flow for water supply and water quality downstream. Water yield studies at Jasper, Indiana indicate that the use of 167,800 acre-feet storage from Patoka Reservoir in the critical low flow period (1952-1956) will produce a firm flow of 198 cubic feet per second without allowance for evaporation. Of this amount 68 cubic feet per second will be applied for water quality and 130 cubic feet per second for water supply, both on an all-season basis.

TABLE 21

AREA AND CAPACITY
PATOKA RESERVOIR, PATOKA RIVER, INDIANA
MILE 118.30

Elev. (ft. m.s.l.)	Area (acres)	Storage Capacity (acre-feet)	Storage Capacity (inches on drainage area)
480	0	0	0
482	7	7	0
484	17	30	0
486	33	80	0.01
488	55	167	0.02
490	85	306	0.03
492	135	521	0.06
494	260	903	0.10
496	435	1,590	0.18
498	685	2,710	0.30
500	985	4,380	0.49
502	1,280	6,650	0.74
504	1,640	9,570	1.07
506	2,010	13,200	1.47
508	2,440	17,600	1.97
510	2,880	23,000	2.56
512	3,380	29,200	3.26
514	3,910	36,500	4.07
516	4,460	44,900	5.01
518	4,980	54,300	6.06
520	5,480	64,800	7.23
522	5,960	76,300	8.51
524	6,410	88,600	9.89
526	6,860	102,000	11.4
528	7,280	116,000	13.0
530	7,680	131,000	14.6
532	8,080	147,000	16.4
534	8,480	163,000	18.2
536	8,880	181,000	20.2
538	9,280	199,000	22.2
540	9,680	218,000	24.3
542	10,100	238,000	26.5
544	10,500	258,000	28.8
546	10,900	280,000	31.2
548	11,300	302,000	33.7
550	11,800	325,000	36.2
552	12,200	349,000	38.9
554	12,700	374,000	41.7
556	13,100	399,000	44.6
558	13,600	426,000	47.6
560	14,000	454,000	50.6

TABLE 21
(Cont'd)

Elev. (ft. m.s.l.)	Area (acres)	Storage Capacity (acre-feet)	Storage Capacity (inches on drainage area)
562	14,500	482,000	53.8
564	14,900	512,000	57.1
566	15,400	542,000	60.5
568	15,800	573,000	63.9
570	16,300	605,000	67.5

D.A. = 168 sq. mi. = 108,000 acres
1" over D.A. = 8,960 acre-feet

Note: Numbers have been rounded to three significant figures.

74. RESERVOIR STORAGE FOR FLOOD CONTROL.

The Standard Project Flood was established in accordance with Civil Engineer Bulletin No. 52-8, dated 26 March 1952, and has a volume of 131,263 acre-feet which is equivalent to 14.65 inches runoff. The spillway crest was established at elevation 550.0 with a total storage of 324,800 acre-feet equal to 36.25 inches runoff. The flood control storage below pool elevation 550.0 and above top of conservation pool (elevation 536.0) is 144,100 acre-feet which is equivalent to a runoff of 16.08 inches.

75. RESERVOIR REGULATION PLAN.

The regulation table, which gives allowable releases to meet flood control requirements downstream from Patoka Reservoir, is based on critical channel capacity of 1,500 cubic feet per second at the Ellsworth gage, and damaging stages at Evansville, Indiana, on the Ohio River, Mt. Carmel, Illinois, on the Wabash River, or at Princeton or Jasper, Indiana, on the Patoka River. Whenever the reservoir pool reaches elevation 550, the downstream control stations are no longer considered, and inflows up to a rate of 1,500 cubic feet per second are released through conduit and spillway. If the pool crests in the elevation range of 550 to 551 gate openings are maintained until pool recedes to spillway crest elevation 550. If the pool reaches elevation 551, the conduit gates are closed until pool recedes to spillway crest elevation 550, and thereafter the discharge is determined by downstream limitations or the Maximum Release rates in table 22. In the plan of conservation pool regulation, the reservoir pool will be maintained as near elevation 536 as possible while supplementing downstream flows as necessary. However, the rate of release of inflows will not exceed 1,500 cubic feet per second nor will the minimum release be less than 25 cubic feet per second. In addition, reservoir regulation is based on river conditions at damage centers at Evansville, Mt. Carmel, Princeton and Jasper. Controlling stage at the U. S. Weather Bureau gage, Evansville, is 37 feet; at U. S. Weather Bureau gage, Mt. Carmel, is 18 feet, at U. S. Geological Survey gage, Princeton, is 9 feet and at U. S. Geological Survey, Jasper, is 2 feet or 2,400 cubic feet per second. The controlling stages are based on the beginning of damage for reaches of the streams represented by the gages with due allowance for time of travel from Patoka Reservoir to the damage points. Table 22 "Schedule for Regulation for Flood Control and Low Flow Regulation" gives the details of procedure for regulation.

76. UTILIZATION OF FLOOD CONTROL STORAGE.

Regulation of the reservoir so as to store excess runoff of twenty-nine flood periods extending from 1944 through September 1961 indicates that the highest reservoir pool attained was elevation 550.17 which occurred during the 1950 flood period. This reservoir pool elevation represents utilization of all of the flood control storage at spillway crest. Table 23 shows results of the reservoir regulation studies.

TABLE 22

SCHEDULE FOR FLOOD CONTROL AND LOW FLOW REGULATION
PATOKA RESERVOIR

Schedule	Controlling Stages (feet) or Discharge (cfs): Ohio River Evansville	Wabash River Mt. Carmel	Patoka River Princeton	Patoka River Jasper	Range in Pool Elevation (feet)	Regulation
A	Below 37	Below 18	Below 9	Below 2,400 cfs	536* - 506**	Maintain Low Flow Regulation Pool as near as possible, providing release indicated in Maximum Release Table is not exceeded. Supplement downstream flows as necessary and outflows are never reduced to less than 25 cfs.
	(All stages or discharges must exist for Schedules A & B)					
B	Same as Schedule A				536* - 550	Release at rate indicated in Maximum Release Table.
C	Above 37 (Any one stage or discharge to exist)	Above 18	Above 9	Above 2,400 cfs	506** - 536*	Release at rate of 25 cfs, plus additional amount required for low flow objectives, if necessary.
					536* - 550***	Release at rate of 100 cfs, plus additional amount required for low flow objectives, if necessary.
D	Control stations no longer considered				550#	When pool elevation 550.0 is attained and likely to be exceeded, release all inflow, provided a flow of 1,500 cfs is not exceeded. When inflow rate exceeds 1,500 cfs, store inflow in excess of 1,500 cfs outflow (conduit + spillway) until elevation 551.0 is attained, after which, conduits will be closed and remainder of flood routed through 600-foot uncontrolled spillway. When inflows into reservoir are diminishing and pool stage is between elevation 551.0 and 550.0 release (conduit + spillway) at rate of 1,500 cfs until pool elevation 550.0 is attained.

Minimum Flow Objectives

Station	Discharge (cfs)	Period
Jasper	125	All Year
Princeton	175	All Year

Maximum Release Table

Natural Jasper Flow (cfs)	Release (cfs)
Below 2,400	1,500
2,400-3,500	1,100
3,500-4,500	750
4,500-5,500	365
Over 5,500	25

* Conservation Pool Elevation
** Silt Pool Elevation
*** Spillway Crest Elevation
\# 1,500 cfs discharge (Spillway only)

TABLE 23

FLOOD CONTROL STORAGE UTILIZATION DATA
PATOKA RESERVOIR

Period of Storage			Maximum Reservoir Pool		Flood Control Storage Utilized*	
Beginning	Ending	Duration (days)	Date	Elevation (ft., m.s.l.)	(1,000 acre-feet)	(percent)
24 Mar 44	5 Apr 44	13	Apr 1	537.0	8.98	6.2
10 Apr 44	25 May 44	46	May 10	540.3	39.68	27.5
3 Mar 45	8 Jul 45	128	Apr 25	546.9	108.96	75.7
30 Sep 45	19 Oct 45	20	Oct 11	537.9	17.34	12.0
29 Nov 45	5 Dec 45	7	Dec 3	536.3	2.88	2.0
27 Dec 45	28 Jan 46	33	Jan 20	538.2	19.86	13.8
12 Feb 46	16 Mar 46	33	Mar 6	538.6	24.18	16.8
1 May 46	20 Jun 46	51	Jun 10	538.9	26.90	18.7
6 Apr 47	2 Jun 47	58	May 11	540.8	45.26	31.4
12 Apr 48	10 May 48	29	Apr 22	538.8	25.77	17.9
2 Jan 49	4 Jun 49	154	Apr 11	549.4	137.70	98.0
2 Jan 50	27 Jun 50	177	Apr 9	550.17	146.10	100.0
26 Nov 50	28 Dec 50	33	Dec 17	538.4	21.46	14.9
5 Jan 51	22 Jun 51	169	Apr 22-May 5	550.0	146.10	100.0
11 Dec 51	13 May 52	155	Apr 10	544.4	81.29	56.4
16 May 53	3 Jun 53	19	May 26	537.1	9.63	6.7
12 Feb 56	25 May 56	102	Mar 28	543.2	69.17	48.0
7 Apr 57	7 May 57	30	Apr 28	538.4	21.92	15.2
22 May 57	20 Jul 57	59	Jun 18	540.8	44.97	31.2
8 Dec 57	18 Feb 58	72	Jan 5	541.5	51.92	36.0
24 Mar 58	14 Apr 58	30	Apr 7	537.3	11.74	8.1
1 May 58	2 Jun 58	32	May 16-23	539.0	27.56	19.1
19 Jul 58	23 Aug 58	35	Aug 7	539.2	29.47	20.4
20 Jan 59	6 Apr 59	76	Mar 4	543.7	74.36	51.6
13 Feb 60	20 Feb 60	7	Feb 18	536.4	3.59	2.5
21 Mar 60	11 Apr 60	21	Apr 6	537.3	11.74	8.1
30 Jun 60	8 Jul 60	9	Jul 4	536.7	6.29	4.4
23 Mar 61	10 Apr 61	19	Mar 23-Apr 7	536.8	7.19	5.0
15 Apr 61	10 Jul 61	87	May 28	545.9	97.77	67.8

* Low flow regulation pool - Elevation 536, capacity 180,700 acre-feet.

Spillway crest - Elevation 550, capacity 324,800 acre-feet.

Flood control storage - 144,100 acre-feet or 16.08 inches runoff from 168 square mile drainage area.

TABLE 24

STANDARD PROJECT STORM
RAINFALL AND RAINFALL EXCESS
ABOVE
PATOKA DAM SITE

Hours After Beginning of Rainfall	6-Hour Rainfall (inches)	Infiltration Loss (inches)	Rainfall Excess (inches)
0-6	0.02	0.02	0
6-12	0.05	0.05	0
12-18	0.22	0.13	0.09
18-24	0.03	0.03	0
24-30	0.12	0.12	0
30-36	0.30	0.12	0.18
36-42	1.40	0.12	1.28
42-48	0.19	0.12	0.07
48-54	0.80	0.12	0.68
54-60	1.96	0.12	1.84
60-66	9.14	0.12	9.02
66-72	1.23	0.12	1.11
72-78	0.04	0.04	0
78-84	0.11	0.11	0
84-90	0.50	0.12	0.38
90-96	0.07	0.07	0
Totals	16.18	1.53	14.65

77. STANDARD PROJECT STORM.

The Standard Project Storm, determined by the method outlined in Civil Engineer Bulletin No. 52-8, Corps of Engineers, dated March 26, 1952, has a volume which is equivalent to 16.18 inches rainfall and 14.65 inches runoff and is shown by 6-hour rainfall amounts in table 24. The Standard Project Storm Isohyetal Pattern was superimposed over the Patoka Reservoir drainage basin to obtain maximum rainfall as shown on plate D-39. To obtain the rainfall-excess amounts, the storm was modified by an initial loss of 0.20 inch and an infiltration rate of 0.02 inch per hour. The infiltration and rainfall-excess amounts are also shown on table 24.

78. STANDARD PROJECT FLOOD.

The Standard Project Storm rainfall-excess was applied to the Ellsworth natural unit hydrograph B, plate D-37, and an assumed base flow was added. The resulting hydrograph was routed through the reservoir in accordance with the schedule of regulation presented in table 22 assuming the reservoir at conservation pool elevation 536 and the downstream control stations all above flood stage at the start of the Standard Project Storm. Outflow was regulated to maintain 100 cubic feet per second discharge and the remainder of the inflow was stored. The reservoir pool crested at elevation 549.4, which is 0.6 foot below spillway crest. Inflow, outflow, and pool elevation hydrographs are shown on plate D-40.

79. OUTLET WORKS.

The outlet works consist of regulating discharge structures and a stilling basin. It is desirable to select a size of conduit such that a discharge of critical bankfull (1,500 c.f.s.) will obtain at or near minimum reservoir pool stage. A 9-foot diameter circular conduit, which is estimated to have a discharge of about 1,350 cubic feet per second at pool elevation 506 and 2,640 cubic feet per second at pool elevation 550, was adopted. The conduit is located near the right abutment of the dam. Three rectangular gates, each 3.75 feet wide by 7.25 feet high, are provided to regulate flow in the conduit. The invert of the conduit at exit is at elevation 479.2. The conduit of 63.6 square feet cross-sectional area have a longitudinal slope of 0.217 percent. Plate D-41 gives the discharge rating of the 9-foot conduit. The stilling basin from the downstream end of conduit is designed on the basis of a reservoir outflow of 1,500 cubic feet per second. Pool elevation 550.0 was adopted as the critical stage for stilling basin design rather than a higher pool because the backwater effect from spillway discharge entering the stream channel downstream from the stilling basin will afford a water cushion for discharge coming from the outlet works. The discharge of 1,500 cubic feet per second at pool elevation 550.0 is accomplished by opening two gates 3.4 feet each. With discharge control at the gates, a depth of 5.4 feet will result at the conduit exit with an average velocity of 37.6 feet per second.

Due to the low existing rock elevation of 475, there is no parabolic vertical transition from exit of conduit to the stilling basin. A flat grade, extending from conduit exit to end sill, was used. Details of stilling basin are shown on plates D-42 and D-43. The tailwater level corresponding to a flow of 1,500 cubic feet per second is estimated to be at elevation 492.0. The jump-height, to satisfy the momentum equation, based on a width of 20 feet and a floor elevation of 479.2 is computed to be at elevation 492.0. The length of the stilling basin was established at 38.5 feet which is about 3.0 times the design jump-height (12.84 feet). The retreat channel which connects the stilling basin with the natural stream is about 1,450 feet in length. The bottom of the channel is 20 feet in width and side slopes are 1 on 3. The retreat channel bottom will have a longitudinal slope of about 0.2 percent from the notch in end sill where its elevation is 479.2 to the confluence with the natural stream at mile 118.0 where its elevation is 475.5 feet. The maximum velocity in the channel for flows up to 1,500 cubic feet per second is estimated to be less than seven feet per second. Since the retreat channel is excavated in earth, riprap will be placed for 100 feet downstream from the end sill of the stilling basin in order to prevent erosion of channel.

80. SPILLWAY.

The 600-foot open-cut spillway is 2,300 feet northeast of the right abutment of the dam. Both the approach and retreat channels will be cut in rock. Side slopes are assumed to be 4 vertical to 1 horizontal in rock and 1 vertical to 3 horizontal in earth. Longitudinal slopes of the approach and retreat channels are assumed to be 0.5 and 1.5 percent, respectively, both downward from the crest at elevation 550. Lengths of the approach and retreat channels are about 225 and 950 feet, measured upstream and downstream, respectively, from the crest. The discharge rating of the spillway is based on critical flow conditions at the control section by means of the critical flow formula:

$$Q = A \left(\frac{Ag}{T}\right)^{1/2}$$

where:

A = area in square feet
g = acceleration of gravity
T = top width of section in feet
Q = discharge in cubic feet per second

The spillway rating curve for reservoir pool elevation was derived by accounting for friction losses between the control section and the entrance to the spillway and for the spillway entrance loss. The spillway rating curve for reservoir pool elevation for spillways with bottom width of 500, 600, and 700 feet at the control section are shown on Plate D-44.

81. SELECTION OF PROBABLE MAXIMUM STORM.

The basis of seasonal variations of the probable maximum rainfall are shown in paragraph 4 and depth values are given in table 1. The seasonal storm for spillway design is that storm runoff which, when routed through the spillway, will produce the maximum reservoir pool stage when the reservoir pool elevation at the beginning of the spillway design flood is the maximum pool for the same season obtained from routings made according to the Reservoir Regulation Plan. Routing made since 1944 indicated the following maximum starting pool elevations by months and the corresponding probable maximum rainfalls.

Month	Maximum reservoir pool elevation at start of spillway flood (Ft. m.s.l.)	Probable maximum precipitation (inches)
April	550.0	18.6
May	550.0	22.0
June	545.0	25.4
All-Season	539.5	28.8

On the basis of preliminary routings for Patoka Reservoir it was determined that the most critical combination of starting pool elevation and probably maximum storm runoff would occur in May. Paragraphs 82 through 89 give the results of spillway determination and the spillway routings.

82. RUNOFF OF PROBABLE MAXIMUM STORM.

Based on studies of infiltration during late spring and summer, a minimum rate of 0.02 inch per hour was selected. Initial loss was assumed to be 0.20 inch. Three hour ordinates of the May envelope of the probable maximum storm were arranged in the sequence which would produce maximum peak discharge in the design flood hydrograph. Table 25 shows the distribution of rainfall, infiltration and rainfall excess by three-hour periods.

TABLE 25

PROBABLE MAXIMUM
MAY DISTRIBUTION FOR
SPILLWAY DESIGN FLOOD
PATOKA RESERVOIR
MAY STORM

3-Hour Period	3-Hour Rainfall (inches)	Infiltration Loss (inches)	Rainfall Excess (inches)
0-3	.40	.20	.20
3-6	.43	.06	.37
6-9	.45	.06	.39
9-12	.46	.06	.40
12-15	.47	.06	.41
15-18	.47	.06	.41
18-21	.48	.06	.42
21-24	.51	.06	.45
24-27	.54	.06	.48
27-30	.57	.06	.51
30-33	.60	.06	.54
33-36	.63	.06	.57
36-39	1.02	.06	.96
39-42	1.59	.06	1.53
42-45	9.50	.06	9.44
45-48	3.91	.06	3.85
	22.03	1.10	20.93

83. INFLOW UNIT HYDROGRAPHS.

The inflow unit hydrographs developed for spillway design were based on an average pool level above elevation 550, which is believed to provide sequence of inflow likely to occur during the spillway floods. The reservoir drainage area was subdivided into the following areas:

(1) The area above the head of reservoir, 80.1 square miles;

(2) Areas adjacent to the reservoir surface totaling 69.5 square miles;

(3) Reservoir surface area 18.4 square miles.

Regimen of flood runoff is defined by inflow unit hydrographs developed for runoff originating above head of the reservoir pool and from runoff contributing to the pool from individual areas along its periphery.

TABLE 26

UNIT HYDROGRAPHS
FOR
HEAD OF RESERVOIR TOTAL AREA
PATOKA RESERVOIR

Sub-Area 1, Drainage Area 80.1 sq. mi., t_R = 6 Hours

Hours	GRAPH 1-A Unit Hydrograph 1-A Unit Hydrographs 1a+1b+1c+1d+1e Q_{pr} = 5,287 cfs, t_{pr} = 7.0 Hrs.	GRAPH 1-B Q_{pr} = 6,609 cfs t_{pr} = 5.6 Hrs.	GRAPH 1-C Q_{pr} = 7,931 cfs t_{pr} = 4.7 Hrs.
0	0	0	0
3	2,628	3,600	5,675
6	5,034	6,500	6,350
9	3,943	3,500	2,970
12	2,432	1,890	1,480
15	1,334	925	550
18	694	400	160
21	412	215	50
24	266	120	0
27	182	50	
30	128	25	
33	88	10	
36	55	0	
39	30		
42	12		
45	2		
48	0		

84. UNIT HYDROGRAPH FOR BASIN ABOVE HEAD OF RESERVOIR.

Area above the head of reservoir, 80.1 square miles, was divided into five sub-areas designated 1-a, representing drainage from 30.8 square miles of Main Stem Patoka River above head of reservoir pool; 1-b, representing drainage from 6.3 square miles of Dillard Creek; 1-c, representing drainage from 8.7 square miles of Hogs Defeat Creek; 1-d, representing drainage from 7.9 square miles of Youngs Creek, and 1-e, representing drainage from 26.4 square miles of eight small tributaries. Unit hydrographs for these areas were developed by synthetic method, due to the absence of observed flow records. Unit hydrograph values thus derived were for peak discharge, time of peak, the discharge at twice the time of peak and base time. These values were related to slope of the valley and size of the drainage area for the condition of uniform distribution of rainfall. These basic 1-hour unit hydrographs were converted to 6-hour unit hydrograph and the 3-hour average values were determined. The 3-hour average ordinates of the five 6-hour unit hydrographs were combined to obtain a total inflow unit hydrograph 1-A shown in table 26, for the 80.1 square mile area above the head of the reservoir. Since storms of a magnitude approaching the probable maximum produce peak discharges of the unit hydrograph that are consistently higher than those computed from records of minor floods, the peak of hydrograph 1-A was increased arbitrarily by 25 and 50 percent. Thus hydrographs 1-B and 1-C each having the same volume as hydrograph 1-A but of different degrees of concentration for the total area at the head of Patoka Reservoir were developed and are shown in table 26. Pertinent unit hydrograph data relative to the sub-area 1, including 3-hour average values of 6-hour hydrograph, is shown on table 26.

85. UNIT HYDROGRAPHS FOR AREAS ADJACENT TO RESERVOIR SURFACE.

Area 2 was divided into numerous minor areas approximately 1.5 square miles each and aggregating 69.5 square miles, adjacent to the reservoir pool. A single composite unit hydrograph for the 69.5 square miles of area, based on a unit hydrograph of a 1.5 square mile drainage area, was developed using the synthetic method described in preceding paragraph. The resultant 3-hour average values of the 6-hour unit hydrograph are shown in table 27.

TABLE 27

TOTAL UNIT HYDROGRAPH
FOR AREAS ADJACENT RESERVOIR POOL
PATOKA RESERVOIR

Time in Hours	Discharge c.f.s.
0	0
3	5.924
6	7.352
9	1.552
12	124
15	0

86. RUNOFF FOR RESERVOIR POOL AREA.

Since the rate of runoff for the surface of the reservoir pool is equal to the rate of rainfall, one inch of rainfall in six hours over 18.4 square miles of pool area, represents a uniform inflow of 1.976 cubic feet per second from area 3. Accordingly, for a rainfall of 1-inch in 6 hours, the following runoff results:

Time in hours	Discharge c.f.s.
0	0
3	1.976
6	1.976
0	0

87. SPILLWAY FLOODS.

Since the volume and time and degree of concentration of runoff into the reservoir cannot be ascertained with a high order of accuracy, it is desirable to estimate the extent of variations in maximum reservoir levels that would obtain from various basic assumptions regarding runoff. By application of the "rainfall-excess" of table 25 to unit hydrographs 1-A and 2, plus the application of "rainfall" from the same table to unit graph 3, the basic provisional spillway flood, designated hydrograph A, was developed. Hydrographs of design storms that reflect greater concentrations of runoff than that indicated for the provisional spillway flood were developed through application of unit graphs 1-B and 1-C, respectively, to increments of rainfall-excess covering the 12-hour period of greatest intensity and substituted in proper time relation for the corresponding runoff computed by use of unit graph 1-A. Hydrographs A, B, and C shown in table 28 were developed by procedures outlined above. Comparative data, showing maximum reservoir inflow 169,000 c.f.s. for the basic provisional spillway flood, peak flow for greater concentration of runoff, and other characteristics, are presented in table 29.

TABLE 28

HYPOTHETICAL HYDROGRAPHS OF RUNOFF FROM
SPILLWAY DESIGN STORM
PATOKA RESERVOIR

(Hours)	Inflow Hydrographs 3-Hour Average Values (cfs) A*	B**	C
0	-	-	-
3	2,531	2,531	2,531
6	6,511	6,511	6,511
9	9,916	9,916	9,916
12	11,715	11,715	11,715
15	12,745	12,745	12,745
18	13,349	13,349	13,349
21	13,783	13,783	13,783
24	14,399	14,399	14,399
27	15,252	15,252	15,252
30	16,202	16,202	16,202
33	17,194	17,194	17,194
36	18,559	18,559	18,559
39	23,541	24,474	26,466
42	41,952	44,847	47,878
45	121,259	132,252	151,102
48	166,258	182,641	188,010
51	105,726	105,967	99,399
54	48,605	40,875	34,160
57	24,292	17,705	12,061
60	12,837	8,045	3,968
63	7,312	3,970	1,257
66	4,601	2,163	294
69	3,077	1,037	55
72	2,121	469	25
75	1,444	199	8
78	916	39	1
81	515	-	-
84	232		
87	65		
90	8		
93	-		

* Basic provisional spillway flood
** Adopted as spillway design flood

TABLE 29

SPILLWAY FLOOD DATA
PATOKA RESERVOIR

Designation of Hydrograph	Volume of Runoff (inches)	Maximum Instantaneous Peak Inflow (1,000 cfs)	Maximum Peak Inflow (cfs per sq.mi.)	Peak Inflow ÷ √D.A. (cfs)	Per Cent of Basic Provisional Flood
A *	20.95	166	988	12,802	100.0
1.25 A	26.19	208	1,238	16,043	125.0
1.50 A	31.43	249	1,482	19,207	150.0
B **	20.95	183	1,089	14,112	110.2
C	20.95	189	1,125	14,586	113.9

* Basic provisional spillway flood
** Adopted as spillway design flood

88. RESULTS OF ROUTING SPILLWAY FLOODS.

Assuming the reservoir water surface at initial pool elevation 550.0 (spillway crest), spillway floods A, 1.25A, 1.5A, B and C were routed through the combined works of conduit and spillway. All inflow less than 1,500 c.f.s. was released through the conduit by gate regulation. When inflow exceeds 1,500 c.f.s. and elevation 551 is to be exceeded release only 1,500 c.f.s. (spillway + conduit) until elevation 551 is attained. Above elevation 551, the conduit is closed and the remainder of the flood is routed on an uncontrolled basis to a peak reservoir stage. Discharge rating curves for conduit and spillway are shown on plates D-41 and D-44, respectively. Plate D-45 shows reservoir elevation-inflow-outflow curves, resulting from flow routings in terms of basic provisional spillway flood volume or peak (hydrograph A). Points on curve P were computed by routing hypothetical hydrographs representing the same volume as the basic provisional spillway flood, but with higher peak rates and greater concentration of runoff. The quantitative effect of possible errors in estimating the critical regimen of runoff from the probable maximum storm are determined from curve P. In contrast, curve V was computed by routing hypothetical hydrographs representing a direct percentage increase in all ordinates of the basic provisional spillway flood hydrograph. The percentage increase in hydrograph ordinates is equivalent to an increase in volume of the design-storm rainfall-excess quantities without change in the assumed regimen of runoff as reflected by the unit hydrograph used in developing the basic provisional spillway flood estimate. A comparison of the slopes of curves P and V then becomes an index to the relative effects of possible errors in estimating the critical volume and regimen of runoff.

89. SPILLWAY DESIGN FLOOD.

After giving proper consideration to the results of procedures outlined in paragraphs 82 to 88 inclusive, with due regard for the elements of safety inherent in many of the end results, it was decided to adopt hydrograph B and the May storm, as the spillway design flood. Starting with spillway crest elevation 550, the spillway design flood, having peak inflow of 183,000 c.f.s. was routed through the combined works (spillway + conduit) to elevation 551 and attained maximum pool elevation 559.6. Inflow-outflow-pool stage hydrographs are shown on plate D-46. The spillway design flood produced a water surface elevation 0.060 foot higher than hydrograph A and 0.10 foot lower than that of hydrograph C.

90. FREEBOARD AND ELEVATION OF TOP OF DAM.

Freeboard was computed by Indiana Flood Control and Water Resources Commission in accordance with procedures outlined in memorandum entitled, "Conference on Determination of Freeboard Requirements for the McGee Bend Dam, Angelina River, Texas." Wind data ranging from 25

to 60 miles per hour were converted to over-water velocities by multiplying by 130 percent. Application of the above data as it pertains to riprapped embankment with 3 to 1 slope, the wave run-up for each of these velocities was then computed. Results of the computations shows that wave run-up plus wind set-up range from 1.5 feet at a lake velocity of 32 miles per hour to 4.2 feet at 78 miles per hour. A freeboard of 5.0 feet, however, is the minimum allowable in the determination of embankment height. The maximum water surface elevation obtained by routing the spillway design flood through the 9-foot conduit and the 600-foot spillway is 559.6 feet. The addition of 5.0 feet of freeboard results in elevation 564.6 feet. The adoption of elevation 565.0 as top of dam provides a freeboard of 5.4 feet.

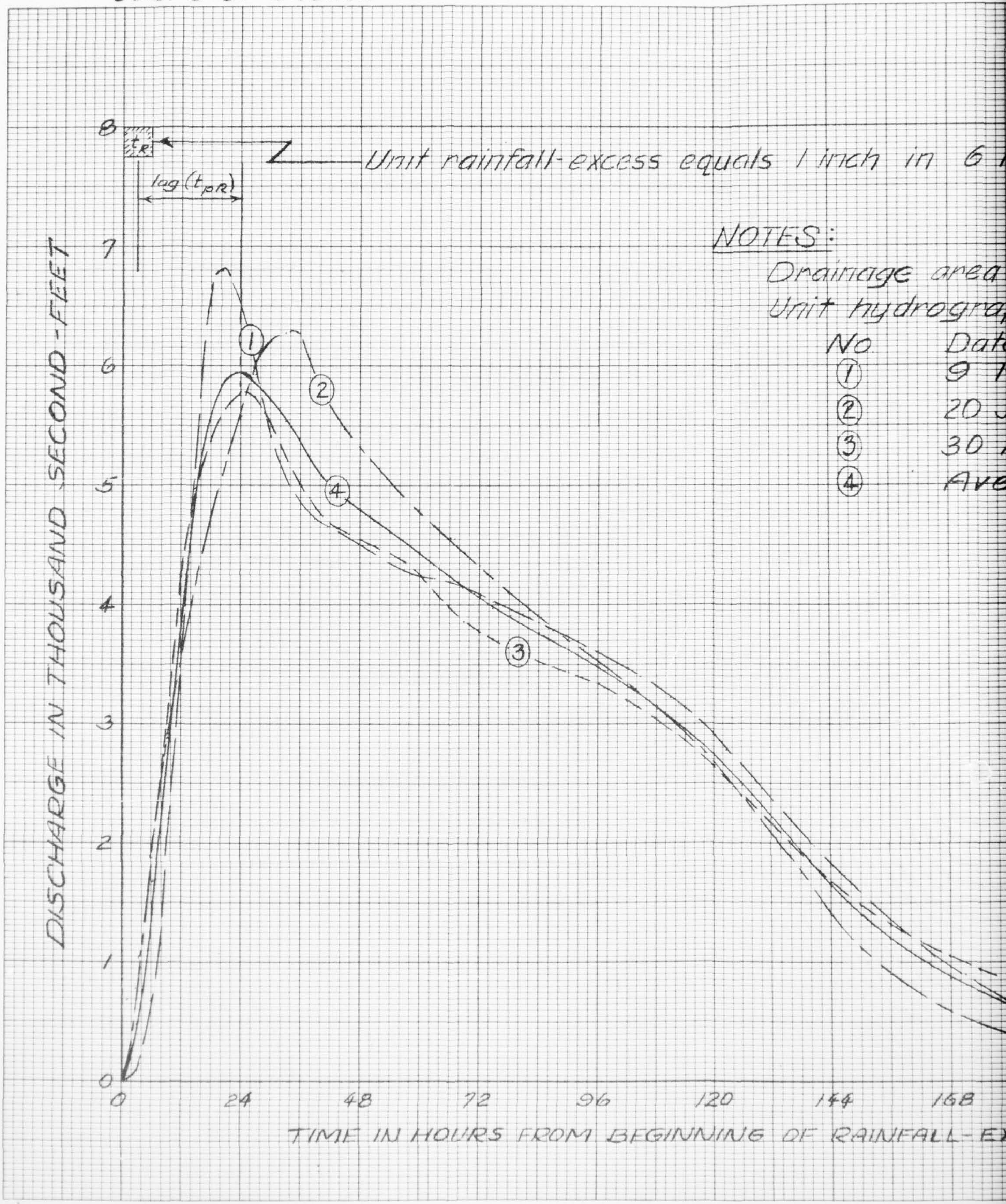
91. NATURAL STAGE - FREQUENCY CURVES.

As stated in paragraph 66a, Patoka River natural flow-frequency curves were evaluated by the Indiana Flood Control and Water Resources Commission. The natural flow-frequency for the Jasper and Princeton, Indiana gages on Patoka River was based on peak annual flood series without standard deviation adjustment by flow volume studies and for a zero skew coefficient. The frequency curves of annual events computed on the basis given above were then converted to a partial-duration curve by use of average criteria derived by Walter Langbein. These criteria are based on the assumption that there are a large number of flood events each year and that these are mutually independent. The reference material for the frequency curves thus determined are found in "Statistical Methods in Hydrology by Leo R. Beard, January 1962." The Jasper and Princeton natural flow frequency curves are shown on plates D-47 and D-48, respectively. Flow-frequency curves were, also, estimated for gaging stations at Winslow and near Ellsworth which were established in June 1961. The flow-frequency curve for the Winslow Station was based on the mean annual flood flow given in open-file report of U. S. Geological Survey, "Floods in Indiana, Magnitudes and Frequency," Indianapolis, Indiana, 1960. This value of the mean flood flow was then adjusted by ratio of mean annual flood flow for the Princeton Station as determined by Indiana Flood Control and Water Resources Commission to that as given in the U. S. Geological Survey report. The adjustment was based on data of the Princeton Station since its flow characteristics are the most similar to that of Jasper. A frequency curve corresponding to maximum annual flood series at Winslow was computed on the basis that magnitudes of mean annual flood at Winslow for various frequencies are in the same ratio to the annual flood at Winslow as are the magnitudes of common frequencies at Princeton are to the mean annual flood at Princeton. The curve of maximum annual floods was then converted to that of partial-duration by means of the Langbein criteria. The flow frequency curve for the Ellsworth Station was developed by similar methods to that of Winslow with Jasper frequency data used instead of that of Princeton. The flow-frequency curve for Mt. Carmel, Illinois was developed as indicated in paragraph 35. Discharge-rating curves were used to convert natural flow-frequency to natural stage-frequency which are shown on plates 49 through 53.

92. MODIFIED STAGE - FREQUENCY CURVES.

Modified frequency curves were determined by applying the reservoir holdouts of ten representative floods (March 1913, January 1937, March 1945, April 1948, February 1949, January 1950, May 1957, January 1959, January 1960, and May 1961) to the natural hydrographs or natural hydrographs modified by Group "A" reservoirs. The Patoka dam site holdouts which were determined by routing the floods according to the reservoir regulation plan, were routed downstream in order to determine reductions and modified flows at the downstream damage gages. The peak modified flows of each flood at the respective damage control station was converted to stage by use of discharge rating curves. The peak modified stage for each of the floods was plotted under the peak natural curve or peak natural curve modified by Group "A" reservoirs for the same frequency. A smooth weighted curve drawn through the modified peak stages gives the modified stage-frequency curves. The modified stage-frequency curves are shown on plates D-49 through D-53.

CORPS OF ENGINEERS



t_R
$\log(t_{pR})$
Unit rainfall-excess equals 1 inch in 6
NOTES:
Drainage area
Unit hydrogra
No
Dat
1
9
2
20
3
30
4
Ave
DISCHARGE IN THOUSAND SECOND-FEET
0
1
2
3
4
5
6
7
8
0
24
48
72
96
120
144
168
TIME IN HOURS FROM BEGINNING OF RAINFALL-E

U.S. ARMY

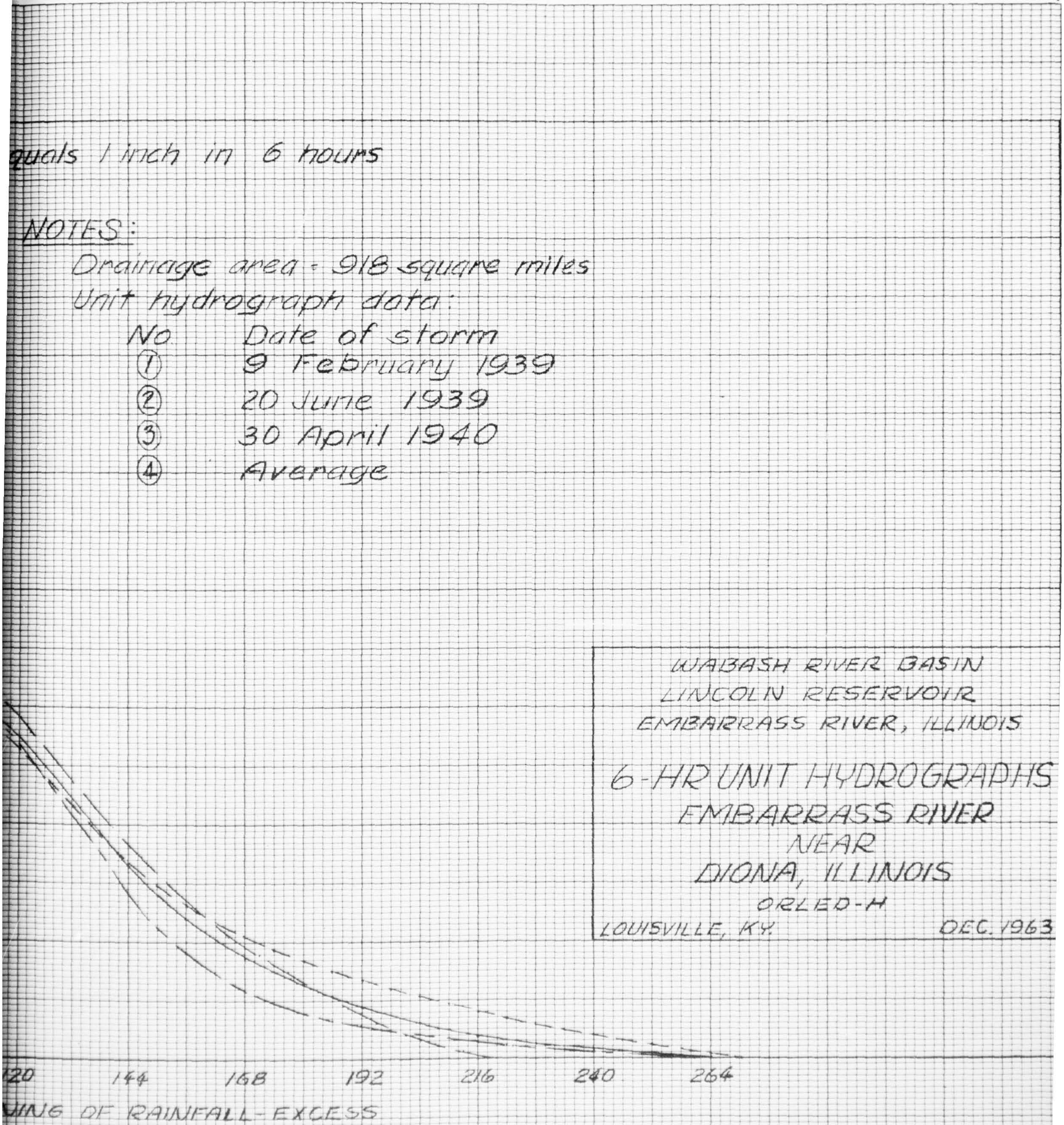
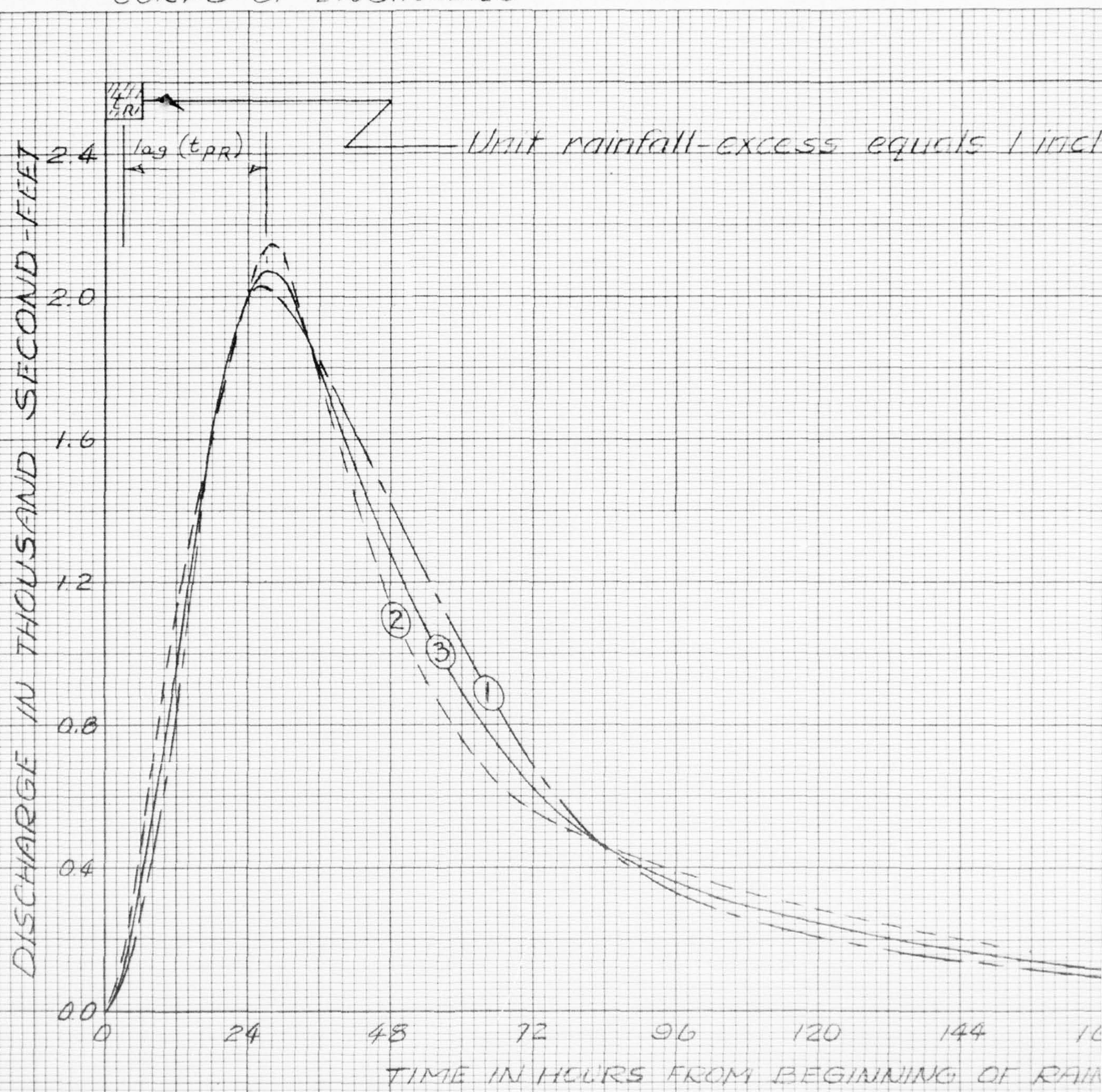


PLATE D-1

CORPS OF ENGINEERS



NOTES:

Drainage area = 185 square miles.

Unit hydrograph data

No.	Date of storm
1	7 May 1961
2	20 March 1962
3	Average

U.S. ARMY

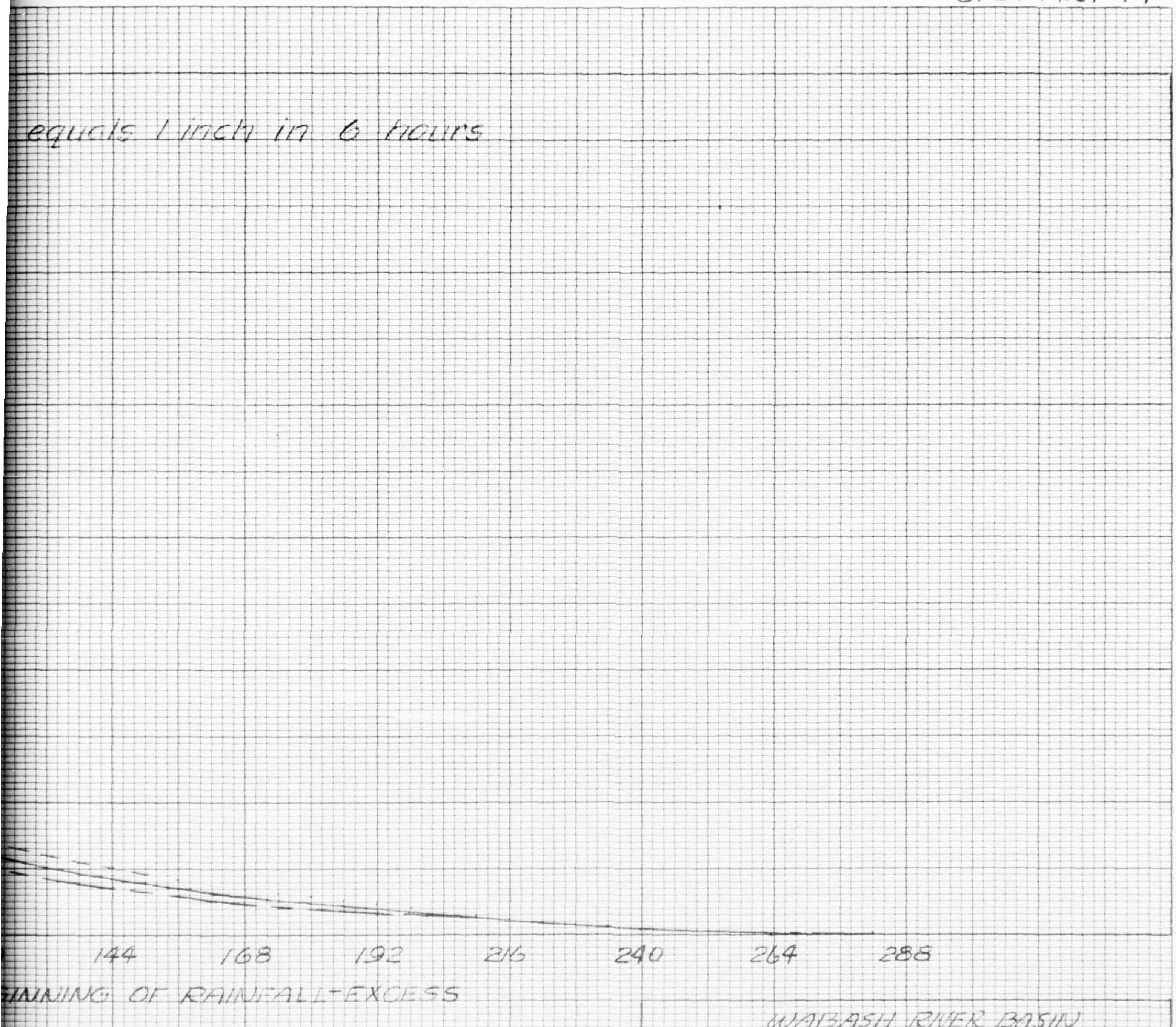
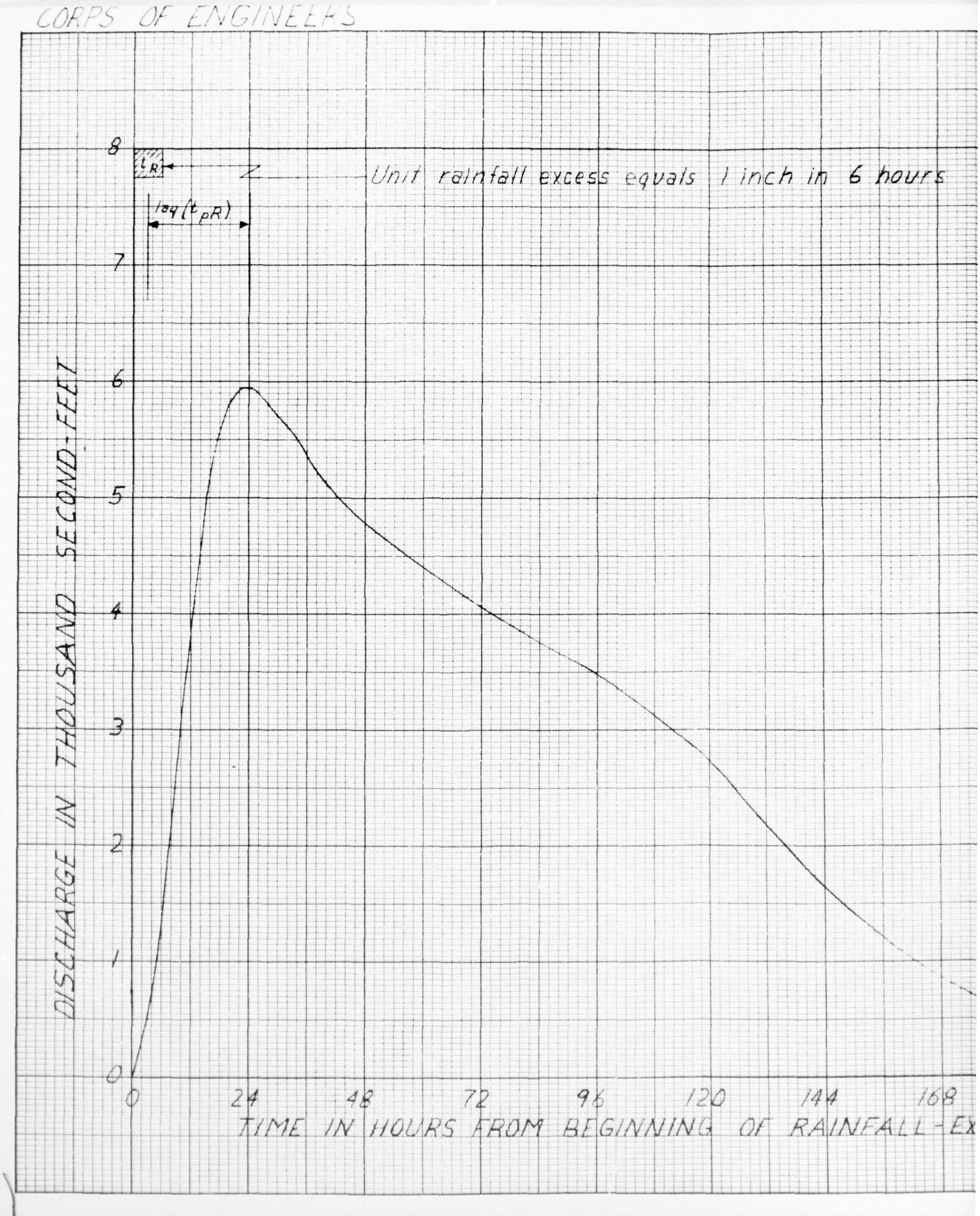


PLATE D-2



CORPS OF ENGINEERS
t_R
lag (t_{pR})
Unit rainfall excess equals 1 inch in 6 hours
DISCHARGE IN THOUSAND SECOND-FEET
0
1
2
3
4
5
6
7
8
0
24
48
72
96
120
144
168
TIME IN HOURS FROM BEGINNING OF RAINFALL-EX

U.S. ARMY

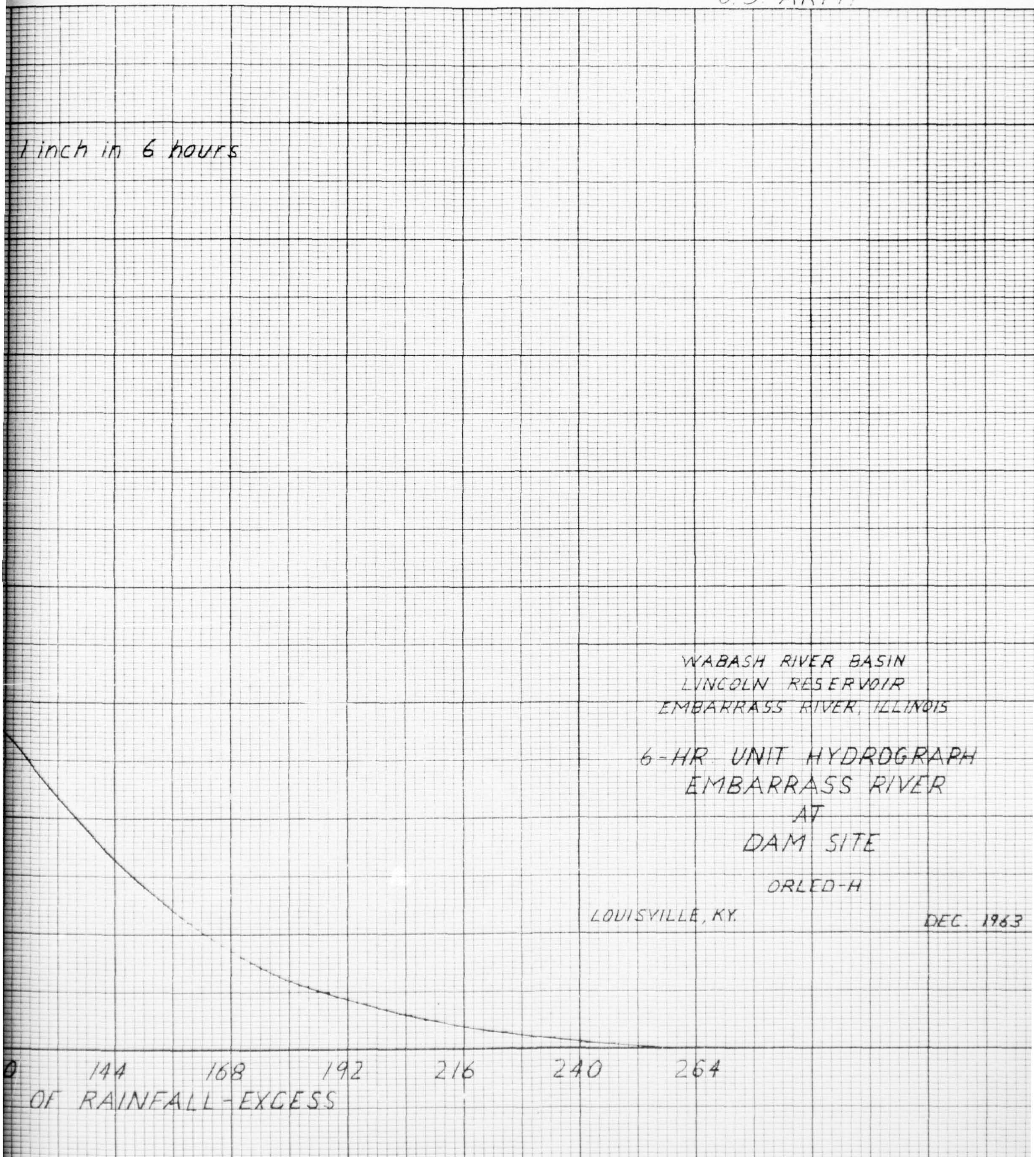
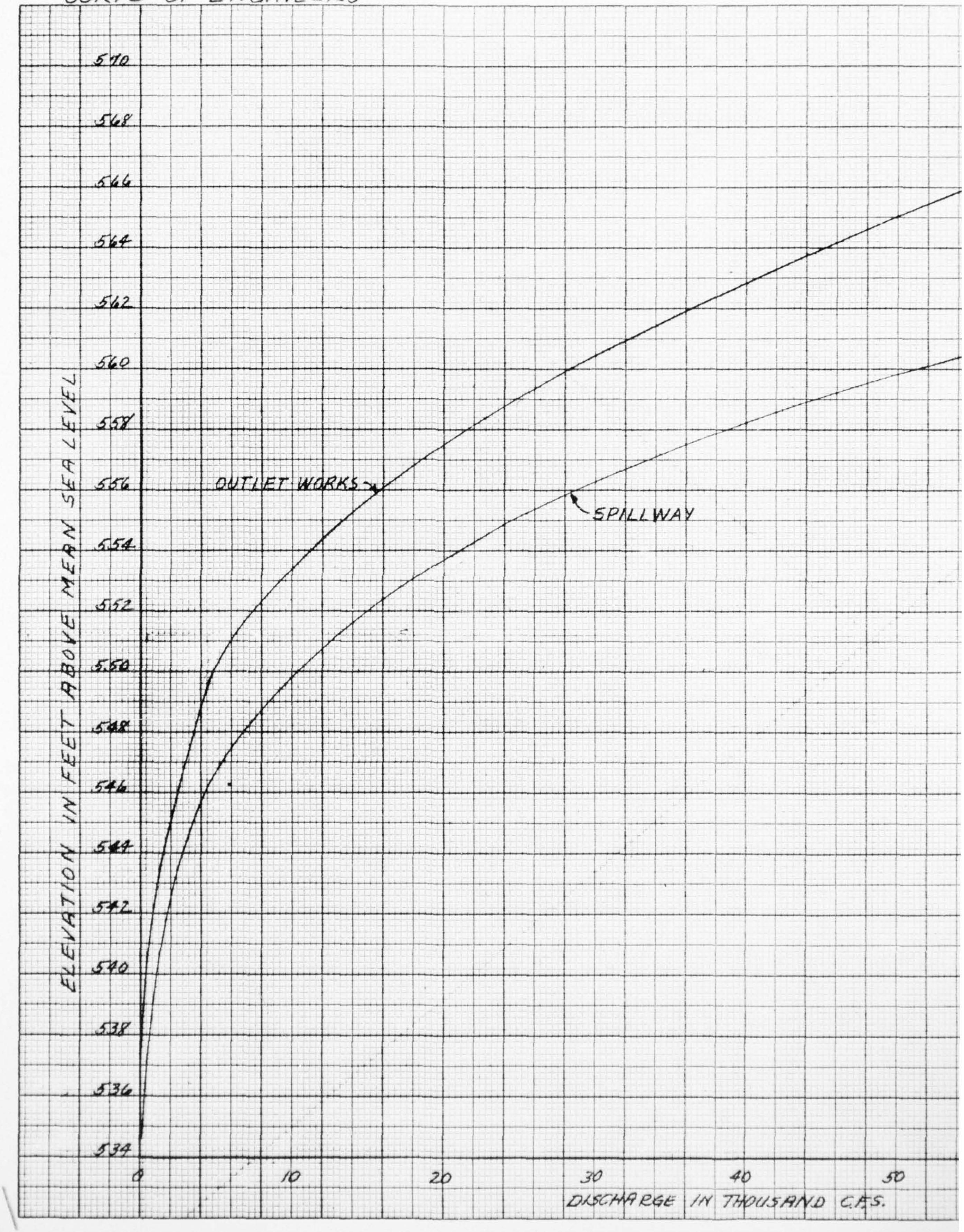
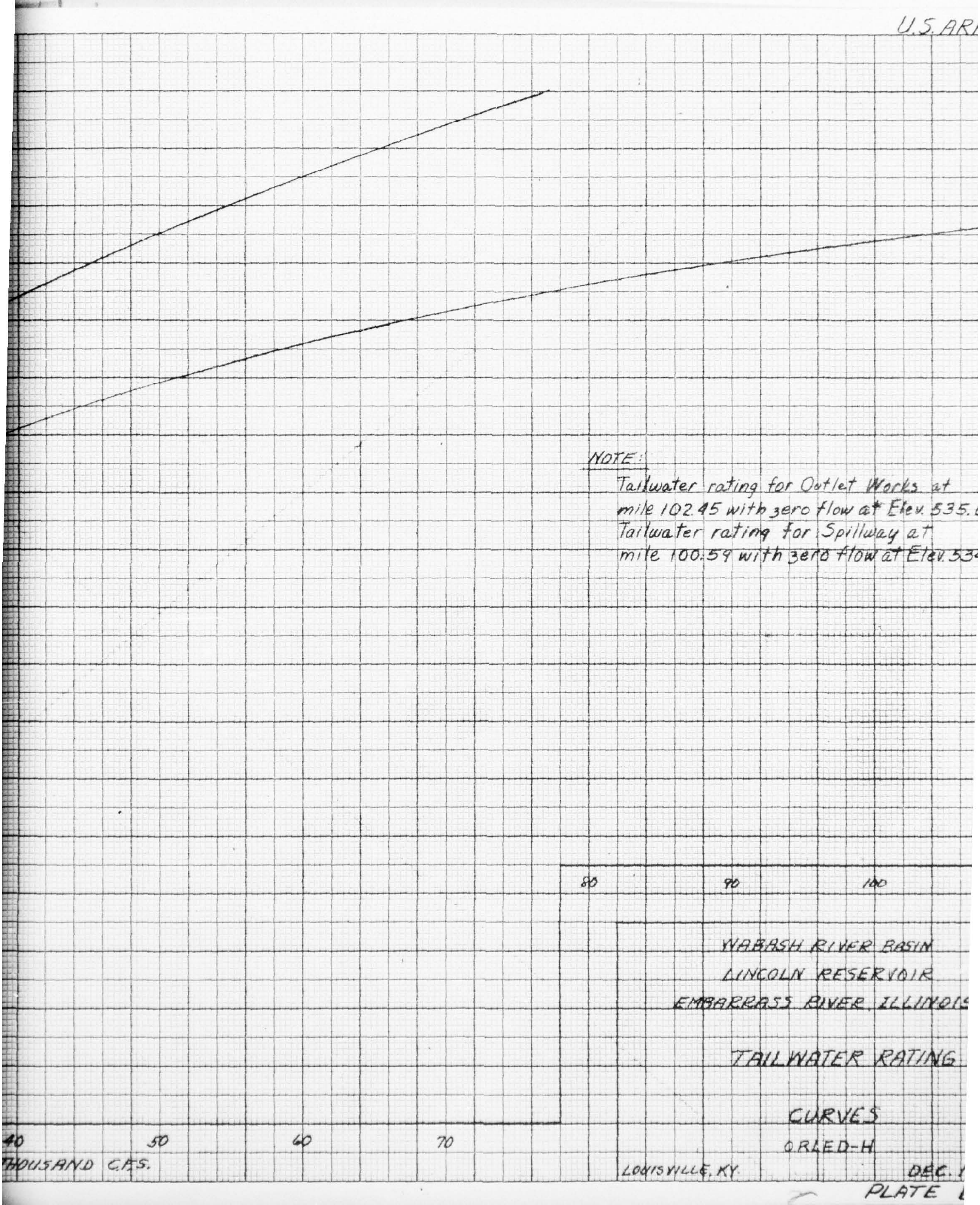
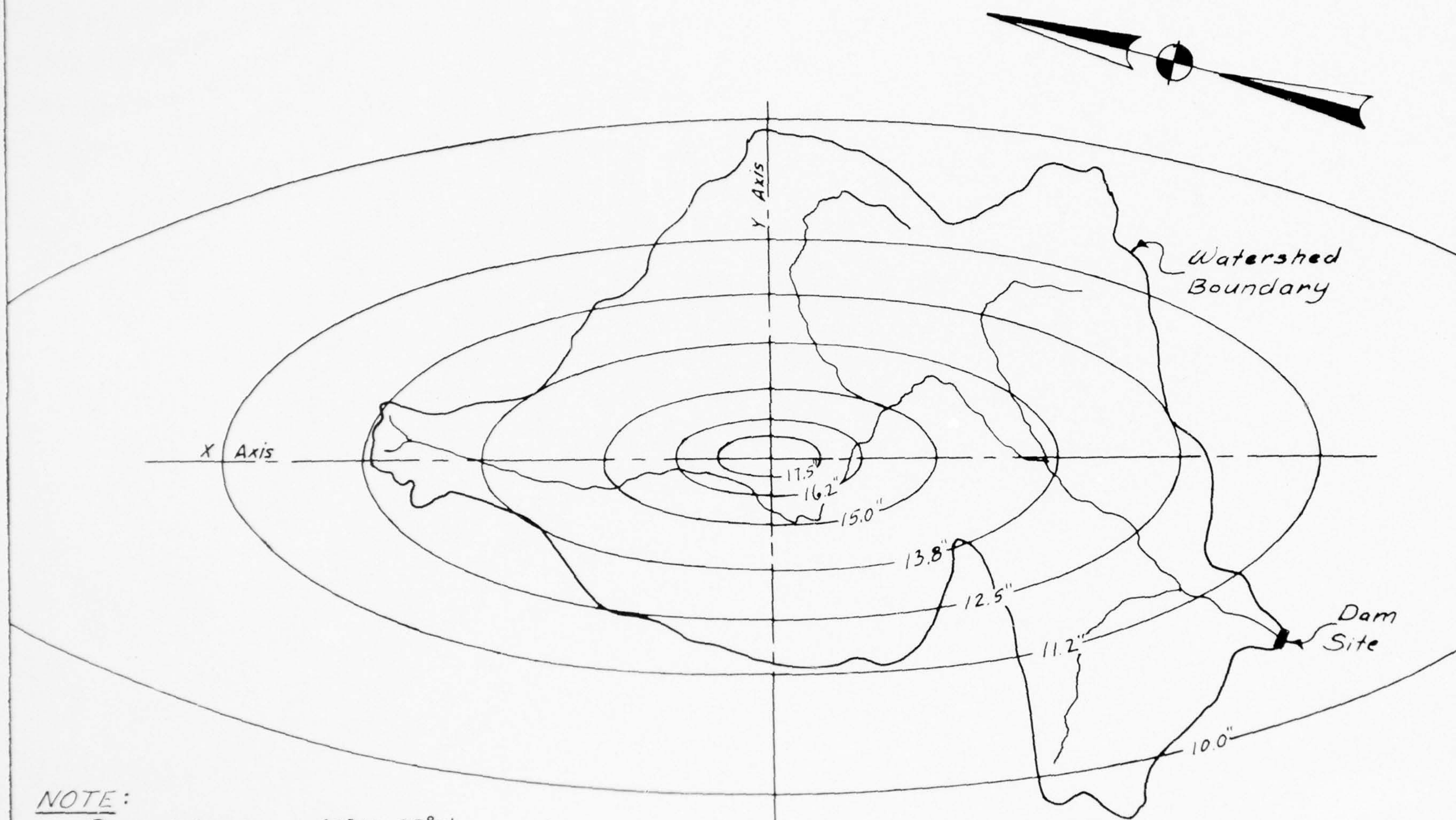


PLATE D-3

CORPS OF ENGINEERS



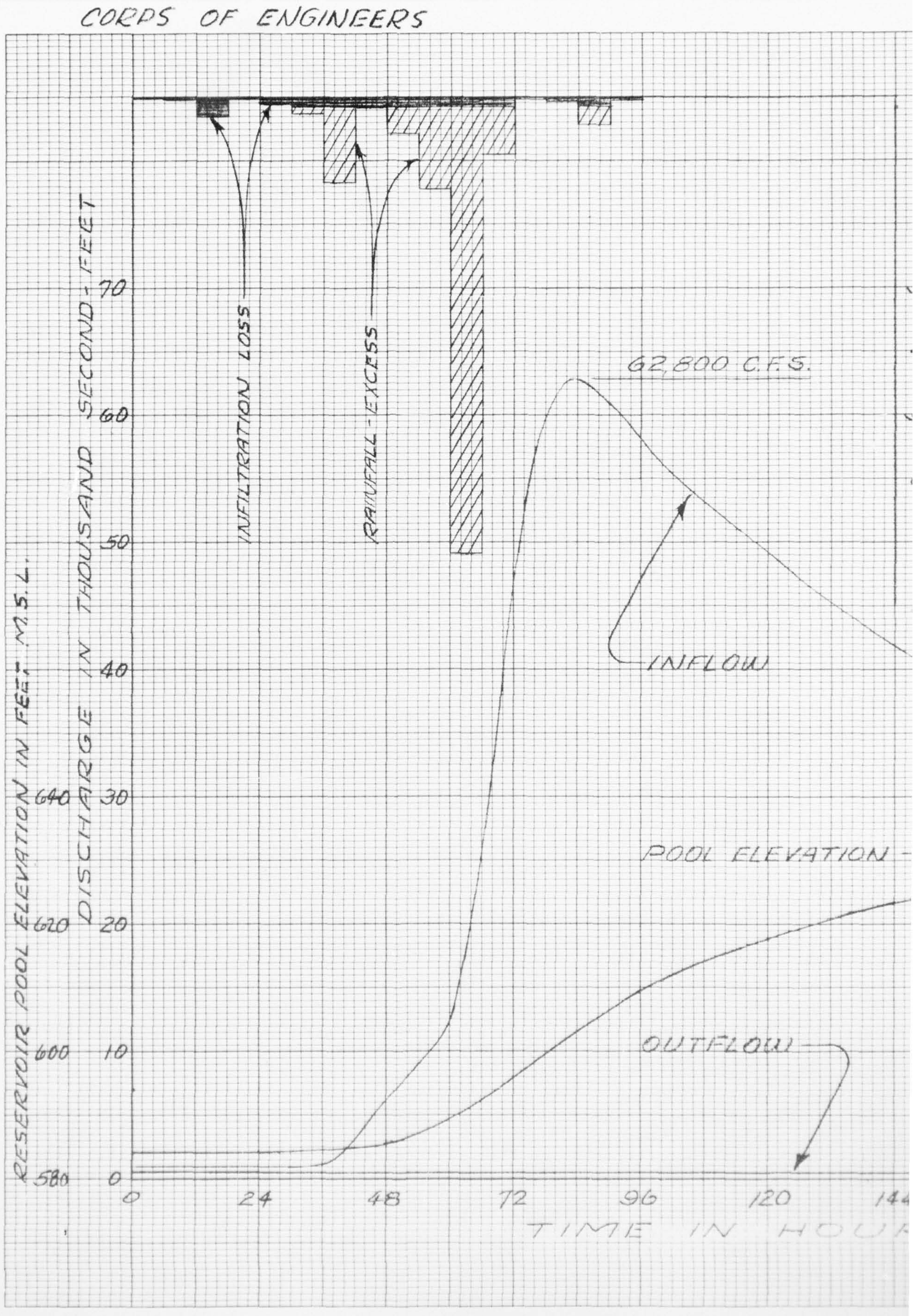

U.S. AR
NOTE:
Tailwater rating for Outlet Works at
mile 102.45 with zero flow at Elev. 535.
Tailwater rating for Spillway at
mile 100.59 with zero flow at Elev. 53
40
50
60
70
80
90
100
THOUSAND C.F.S.
WABASH RIVER BASIN
LINCOLN RESERVOIR
EMBARRASS RIVER ILLINOI
TAILWATER RATING
CURVES
ORLED-H
LOUISVILLE, KY.
DEC.
PLATE



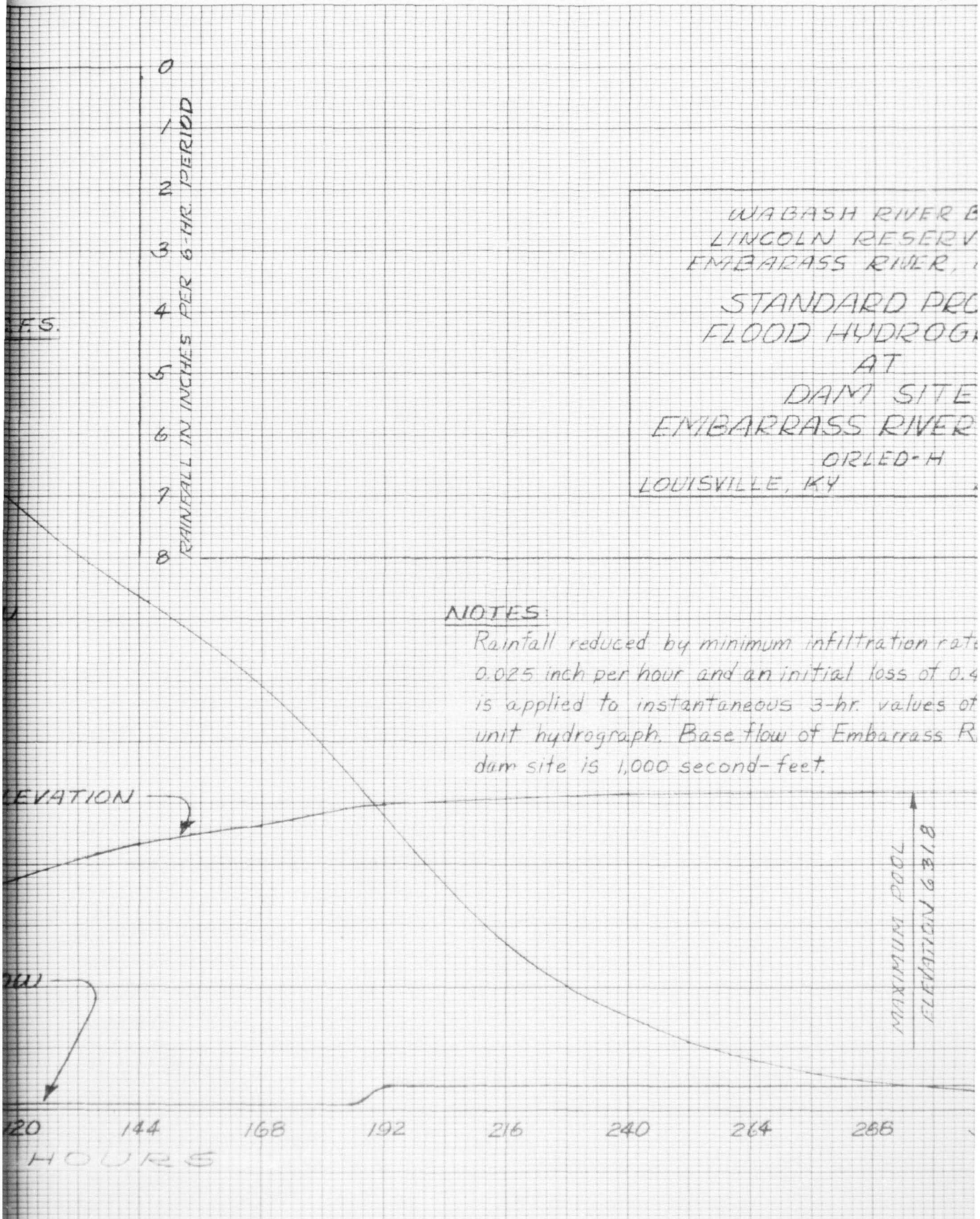
NOTE:
Project location: 40°N, 88°W
Index rainfall = 12.5 inches
Isohyets represent 96-hour rainfall amounts

SCALE = 1/500,000

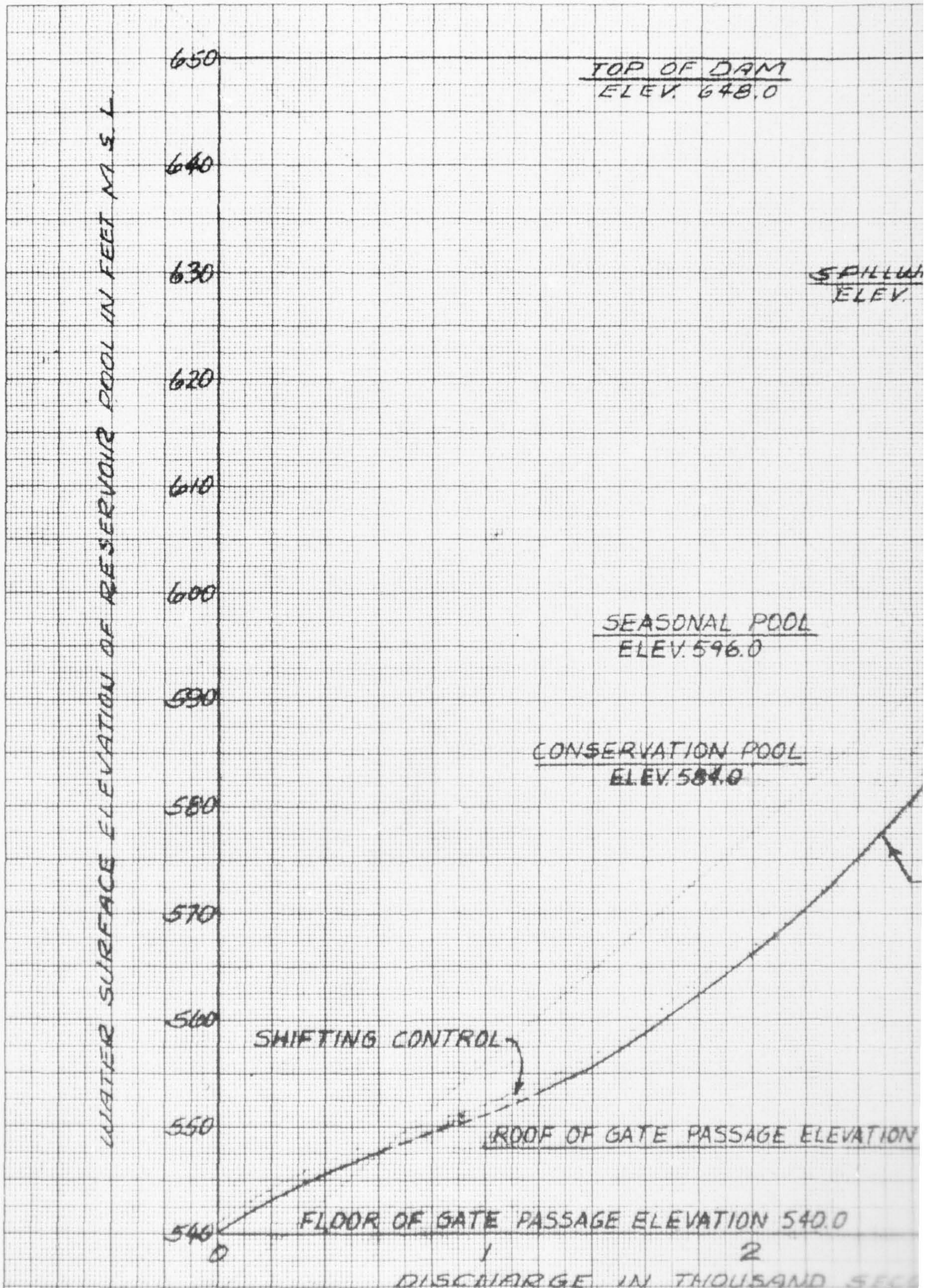
WABASH RIVER BASIN
LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS
STANDARD PROJECT STORM ISOHYETAL PATTERN
LINCOLN DAM SITE, EMBARRASS RIVER, MI. 103
ORLED-H



CORPS OF ENGINEERS
INFILTRATION LOSS
RAINFALL - EXCESS
62,800 C.F.S.
INFLOW
POOL ELEVATION
OUTFLOW
DISCHARGE IN THOUSAND SECOND - FEET
RESERVOIR POOL ELEVATION IN FEET M.S.L.
70
60
50
40
640 30
620 20
600 10
580 0
0
24
48
72
96
120
TIME IN HOU


U.
WABASH RIVER B
LINCOLN RESERV
EMBARASS RIVER,
STANDARD PRO
FLOOD HYDROG
AT
DAM SITE
EMBARRASS RIVER
ORLED-H
LOUISVILLE, KY
0
1
2
3
4
5
6
7
8
RAINFALL IN INCHES PER 6-HR. PERIOD
NOTES:
Rainfall reduced by minimum infiltration rat
0.025 inch per hour and an initial loss of 0.4
is applied to instantaneous 3-hr. values of
unit hydrograph. Base flow of Embarrass R
dam site is 1,000 second-feet.
EVATION
MAXIMUM POOL
ELEVATION 631.8
120
144
168
192
216
240
264
288
HOURS

CORPS OF ENGINEERS



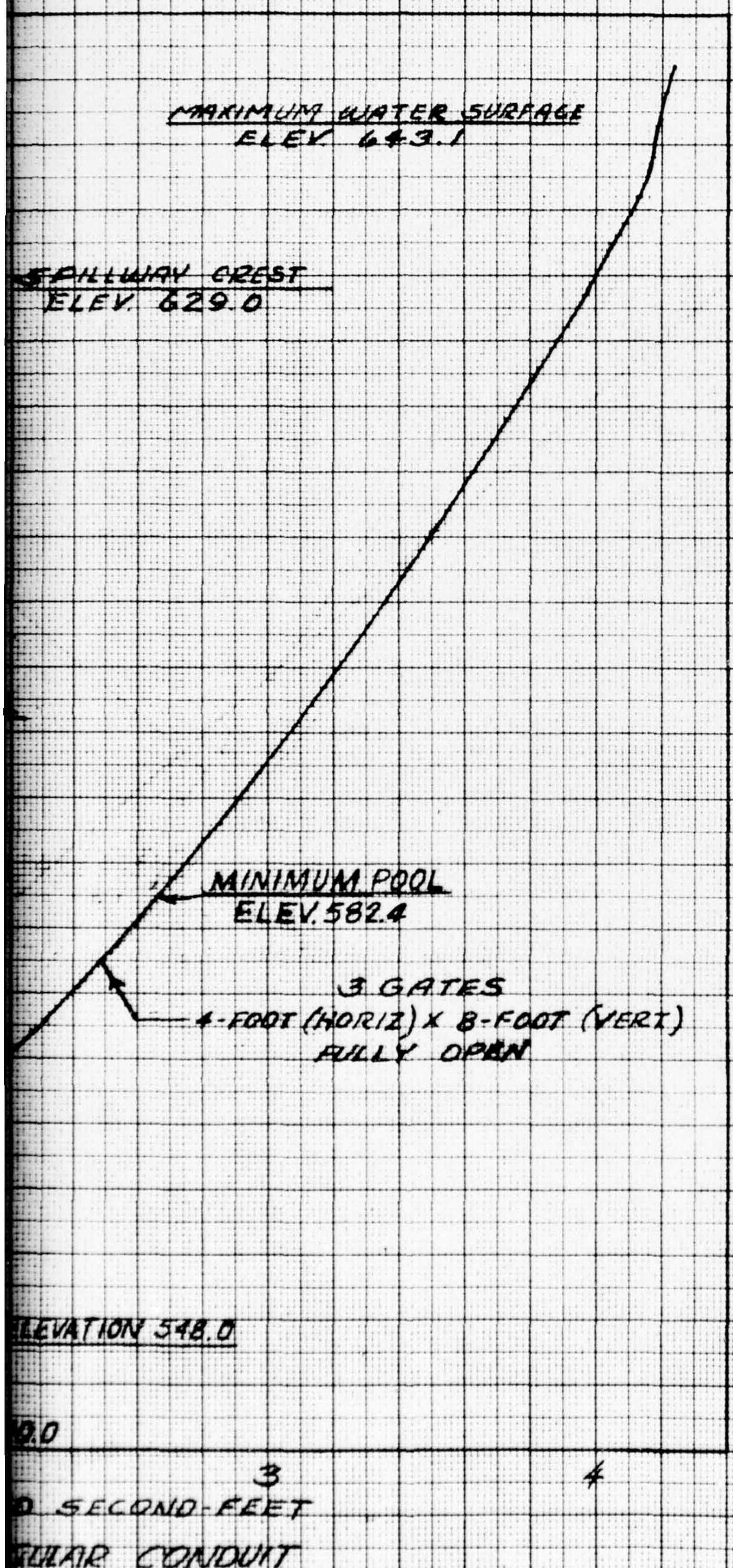
RATING OF 10-FOOT CIRCULAR

AD-A036 533 ARMY ENGINEER DISTRICT LOUISVILLE KY F/G 8/6
WABASH RIVER BASIN COMPREHENSIVE STUDY COVERING RESERVOIR SITES--ETC(U)
JAN 64

UNCLASSIFIED NL

2 OF 7
AD
A036533

U.S. ARMY



WABASH RIVER BASIN
LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS

OUTLET DISCHARGE RATING CURVE

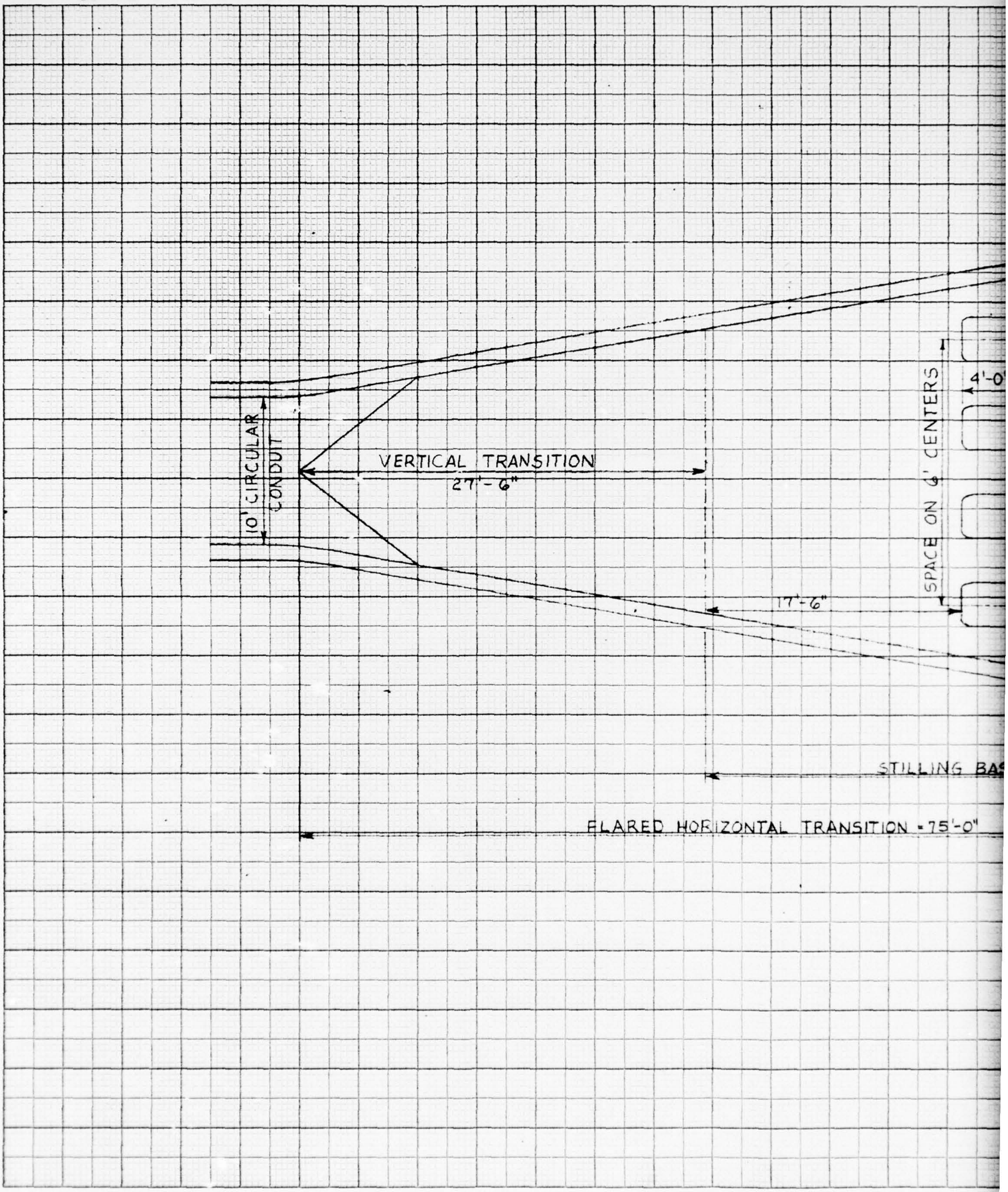
ORLED-H
LOUISVILLE, KY

DEC. 1963

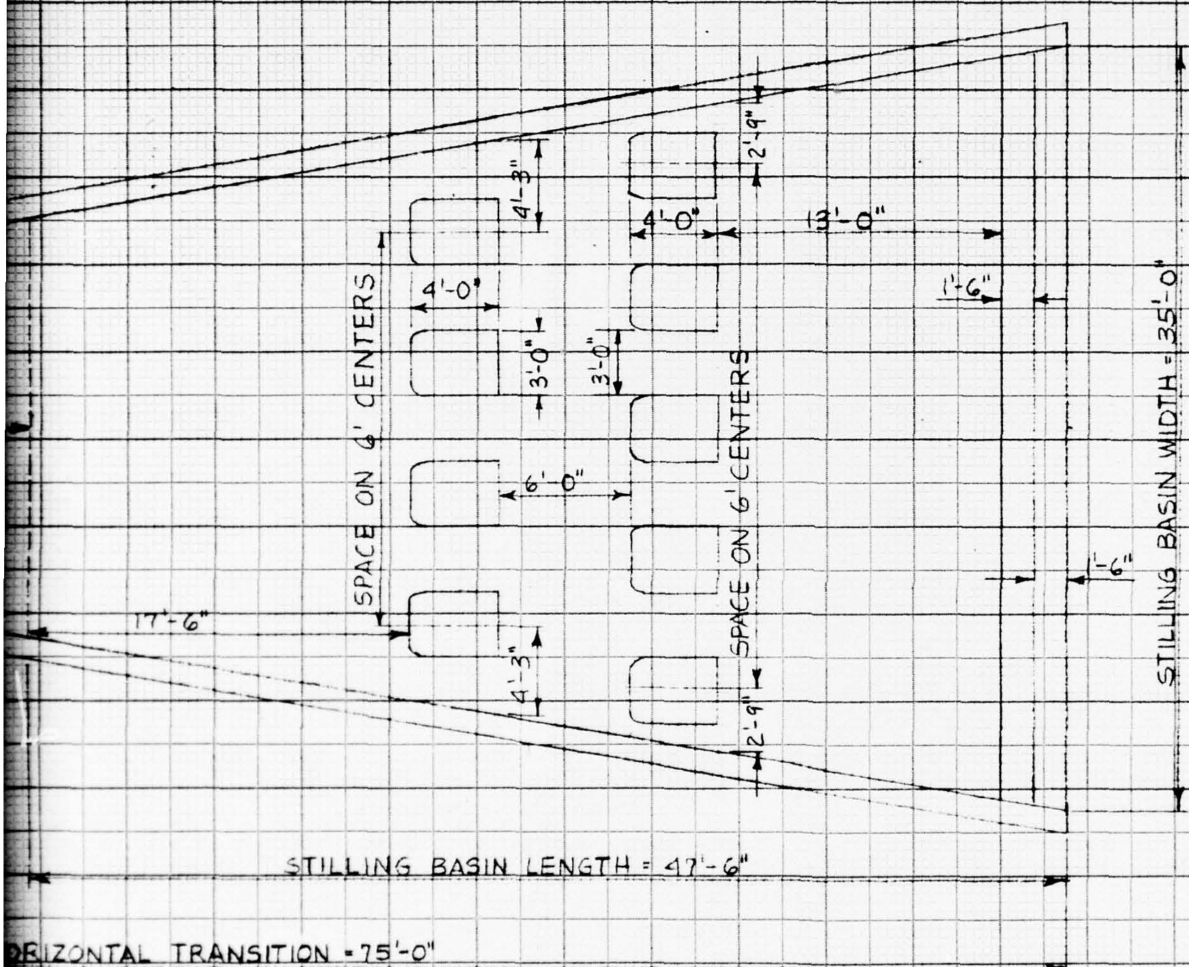
2

PLATE D-7

CORPS OF ENGINEERS



U.S. ARMY



WABASH RIVER BASIN
LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS

PLAN
OF
STILLING BASIN

SCALE: 1/8" = 1.0'

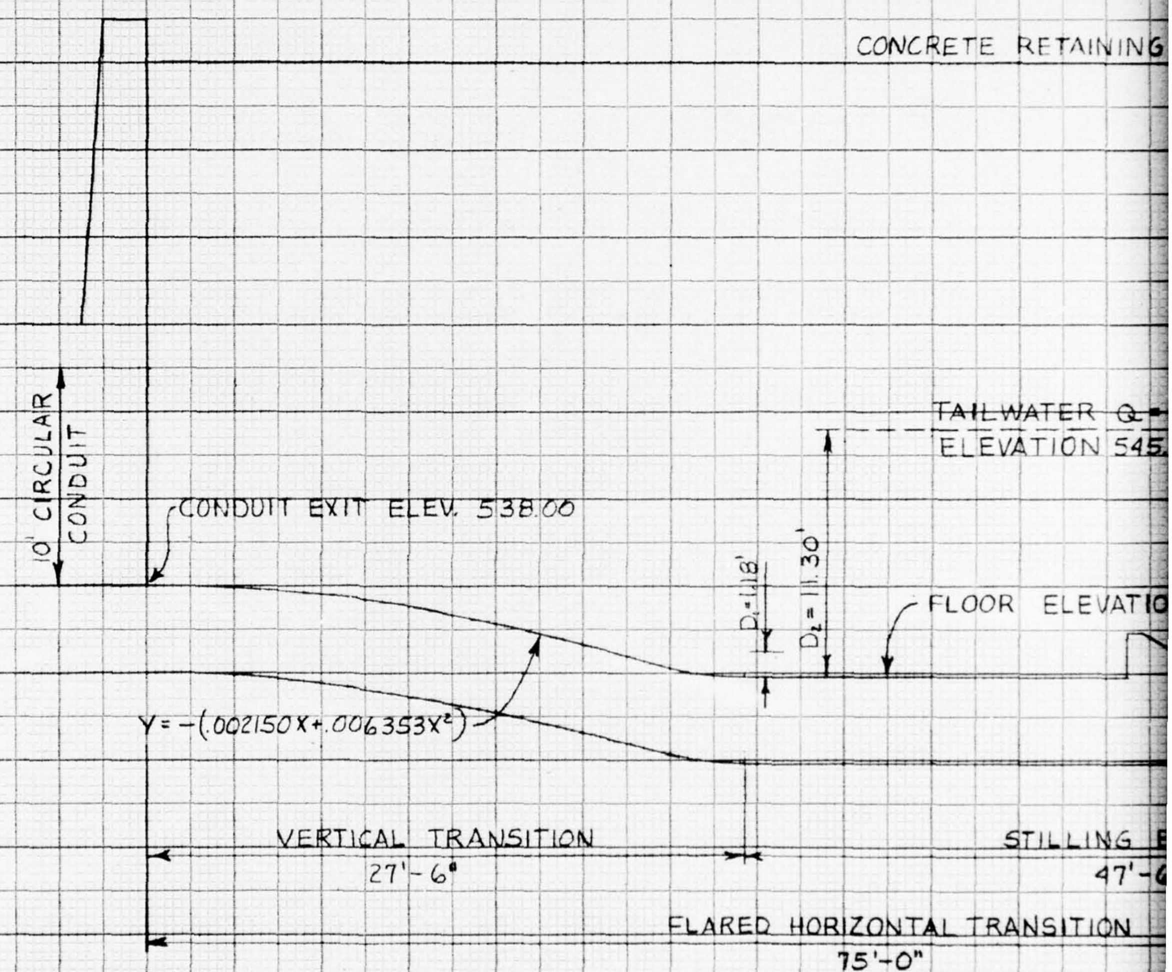
ORLED-H

LOUISVILLE, KY. DEC. 1963

PLATE D-8

2

CORPS OF ENGINEERS

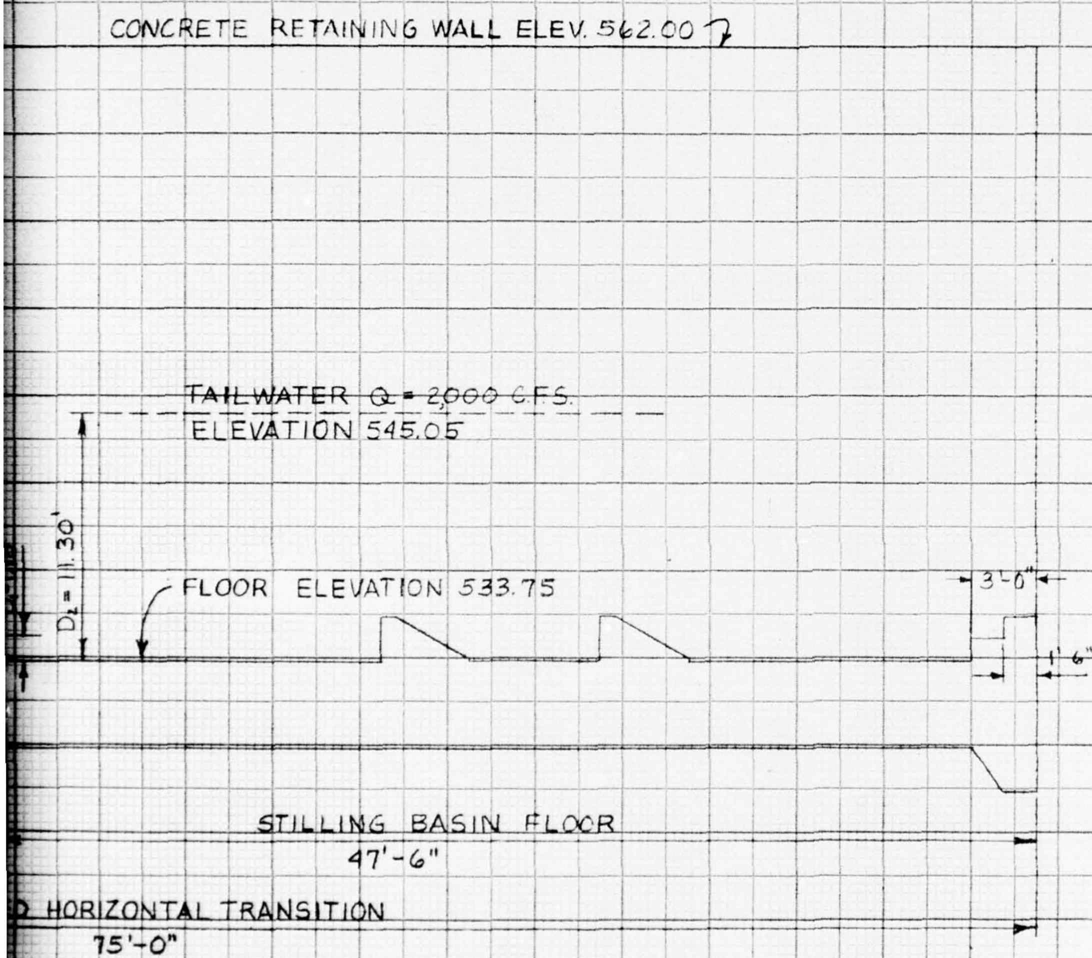


SECTION OF STILLING BASIN

NOTE:

The stilling basin is designed on a basis of pool elevation 62
release of 2,000 c.f.s. which requires two gates to be 4.0 feet a
remaining gate closed. Width in transition range varies from 1
conduit exit to 35 feet at end of horizontally flared section at

U.S. ARMY



OF STILLING BASIN

basis of pool elevation 629.0 for a
two gates to be 4.0 feet and the
sition range varies from 10 feet at
izontally flared section at end sill.

WABASH RIVER BASIN
LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS

HYDRAULIC ELEMENTS
OF
STILLING BASIN

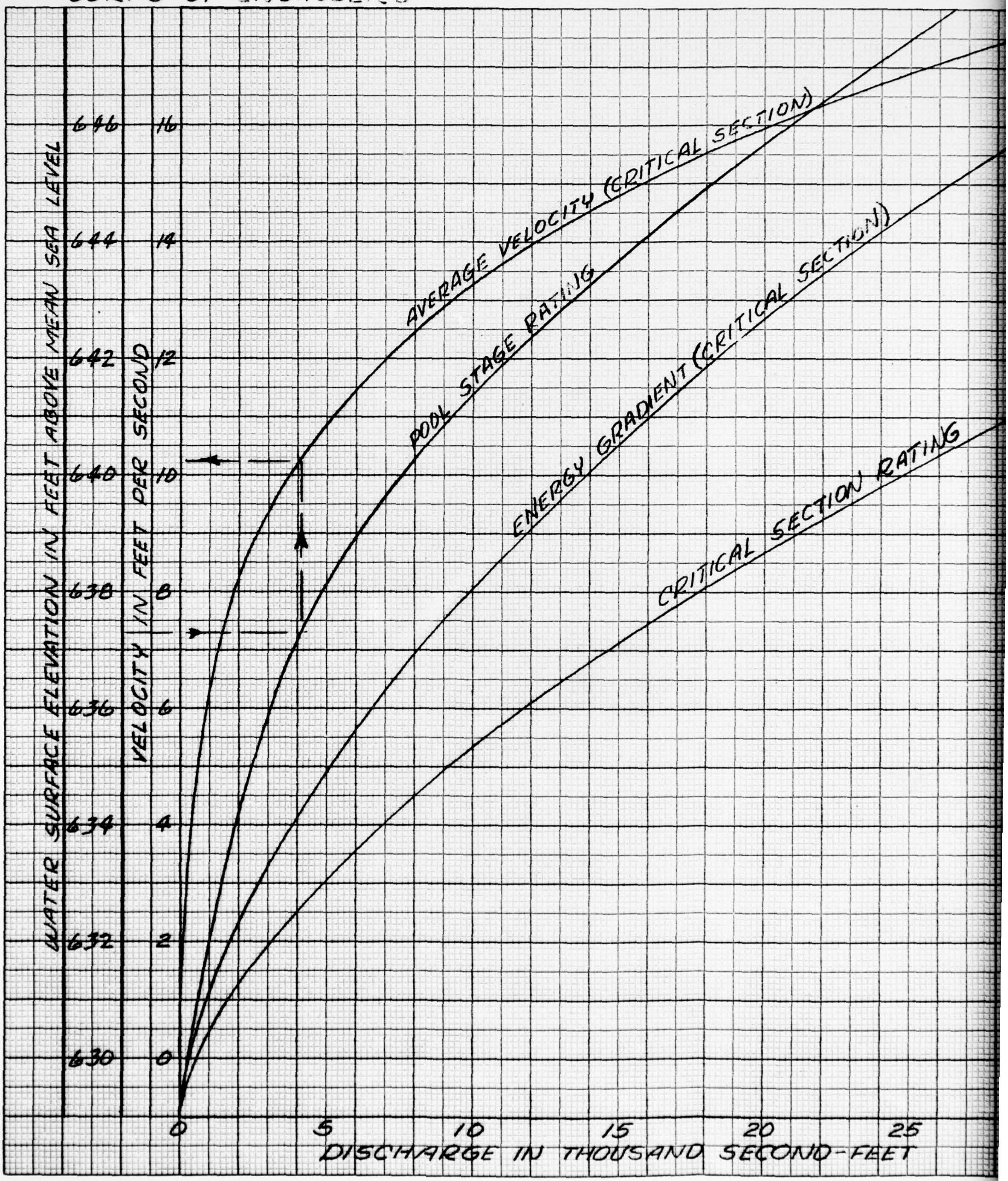
SCALE: 1/8" = 1.0'

ORLED-H

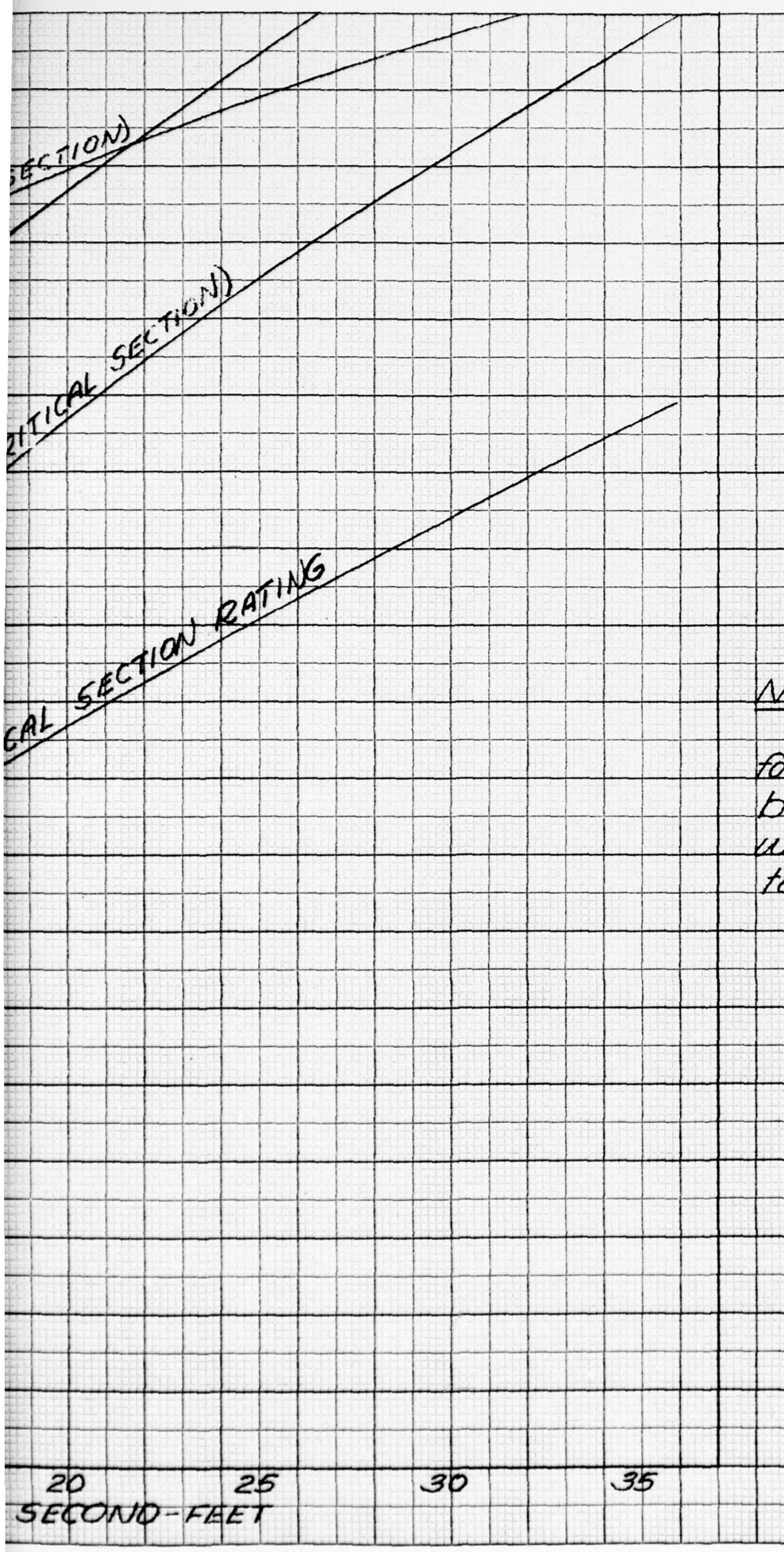
LOUISVILLE, KY. DEC. 1963

PLATE D-9

CORPS OF ENGINEERS



U.S. ARMY



NOTE:
Channel spillway of 100-foot base width has flat bottom at elevation 629.0 with side slopes 1 vertical to 3 horizontal.

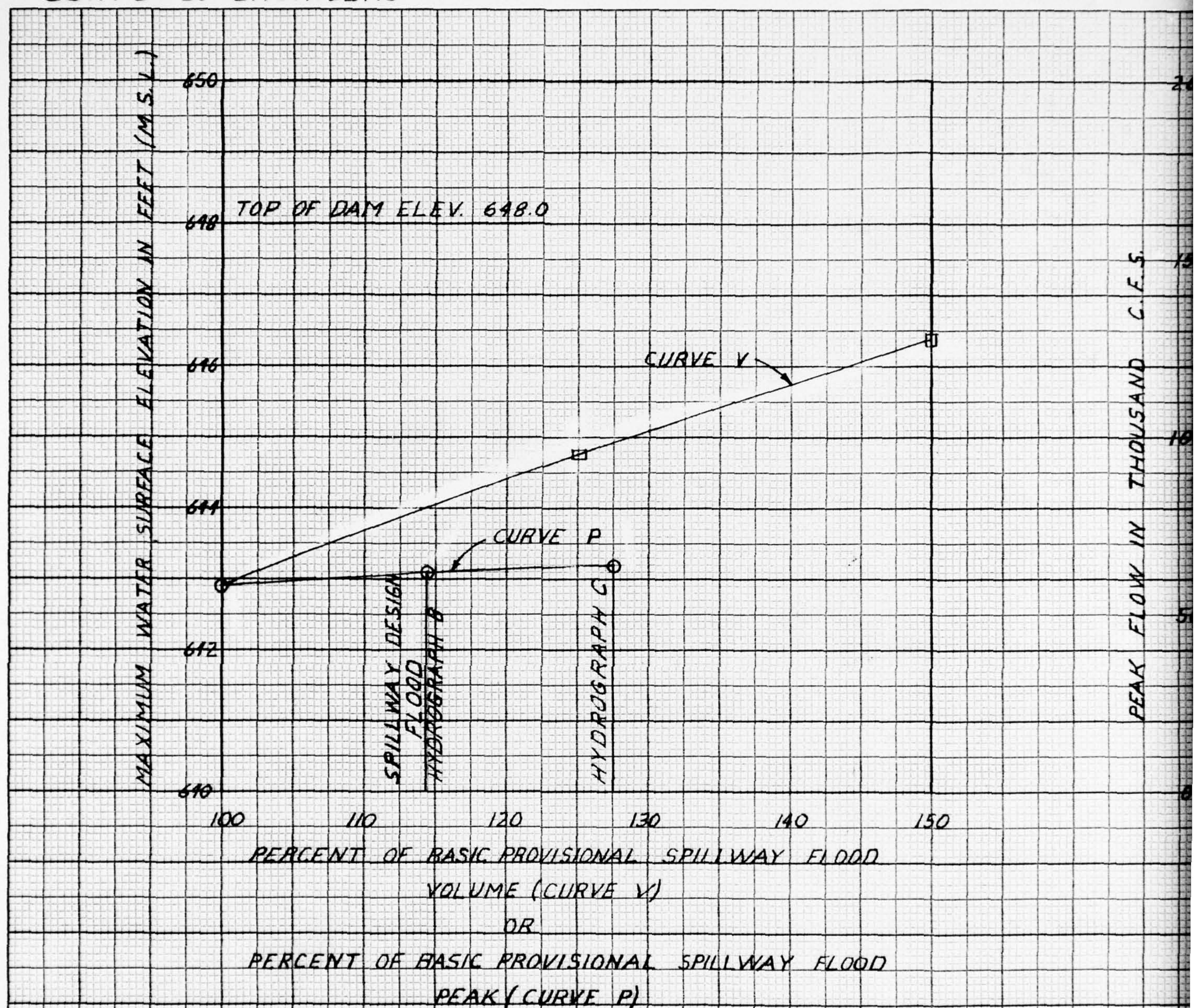
WABASH RIVER BASIN
LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS

SPILLWAY CHARACTERISTIC CURVES

ORLED-H
LOUISVILLE, KY DEC. 1963

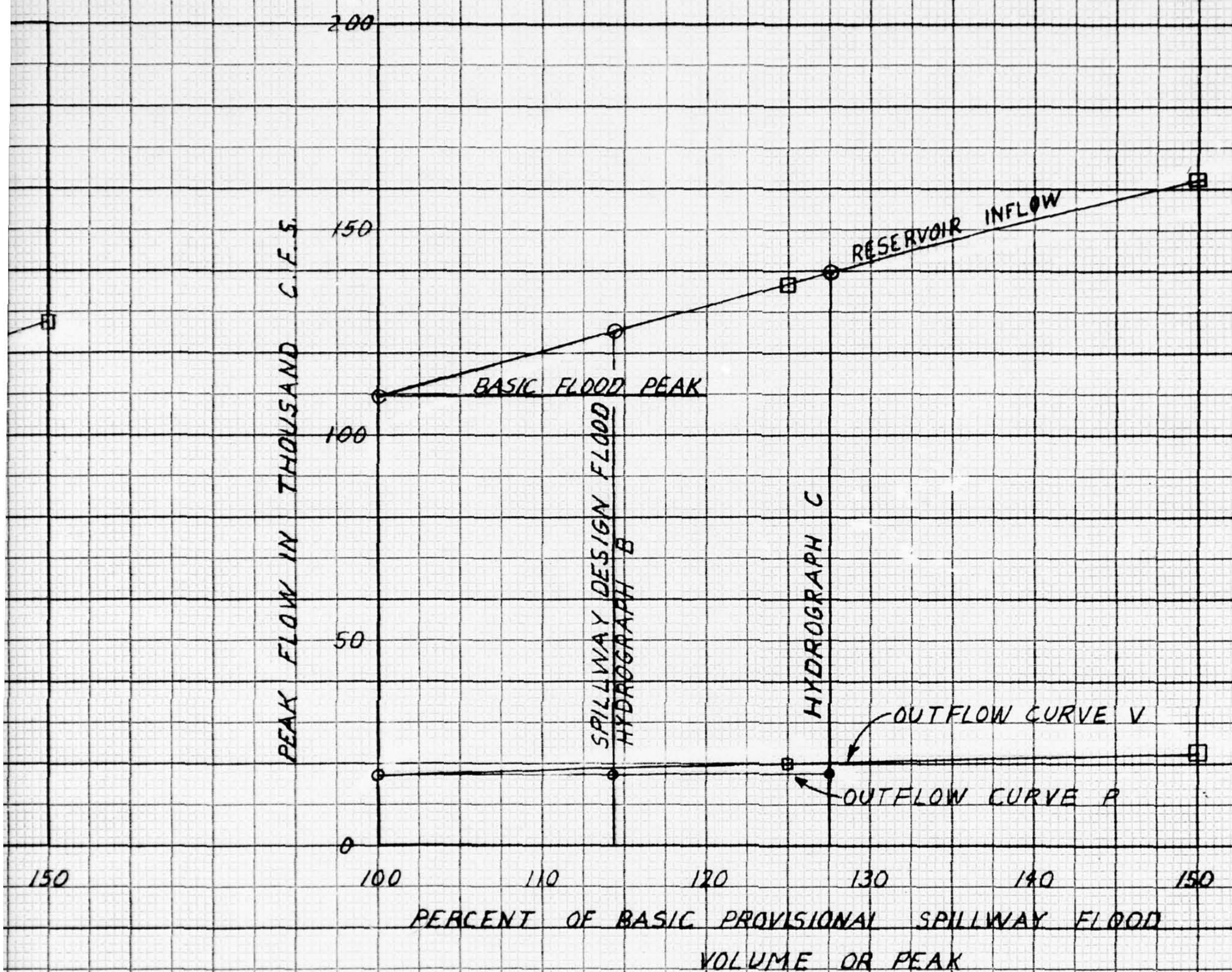
PLATE D-10

CORPS OF ENGINEERS



NOTE:

Curves V and P represent results of routings, assuming open-cut channe
629.0, initial pool elevation 629.0 and conduit gates operative. All inflow
to 3,980 c.f.s. with pool stationary at elevation 629.0. When inflow exce
mainder of flood is routed through the combined works of conduit and
elevation. Curve V represents a volumetric variation in the basic f
remaining constant. Curve P represents a variation in the unit hydrogr
taining constant volume.



ning open-cut channel spillway, bottom elevation
operative. All inflow is released for flows up
When inflow exceeds 3,980 c.f.s. the re-
ks of conduit and spillway to a peak pool
tion in the basic flood, the unit hydrograph
in the unit hydrograph peaks while main-

WABASH RIVER BASIN

LINCOLN RESERVOIR

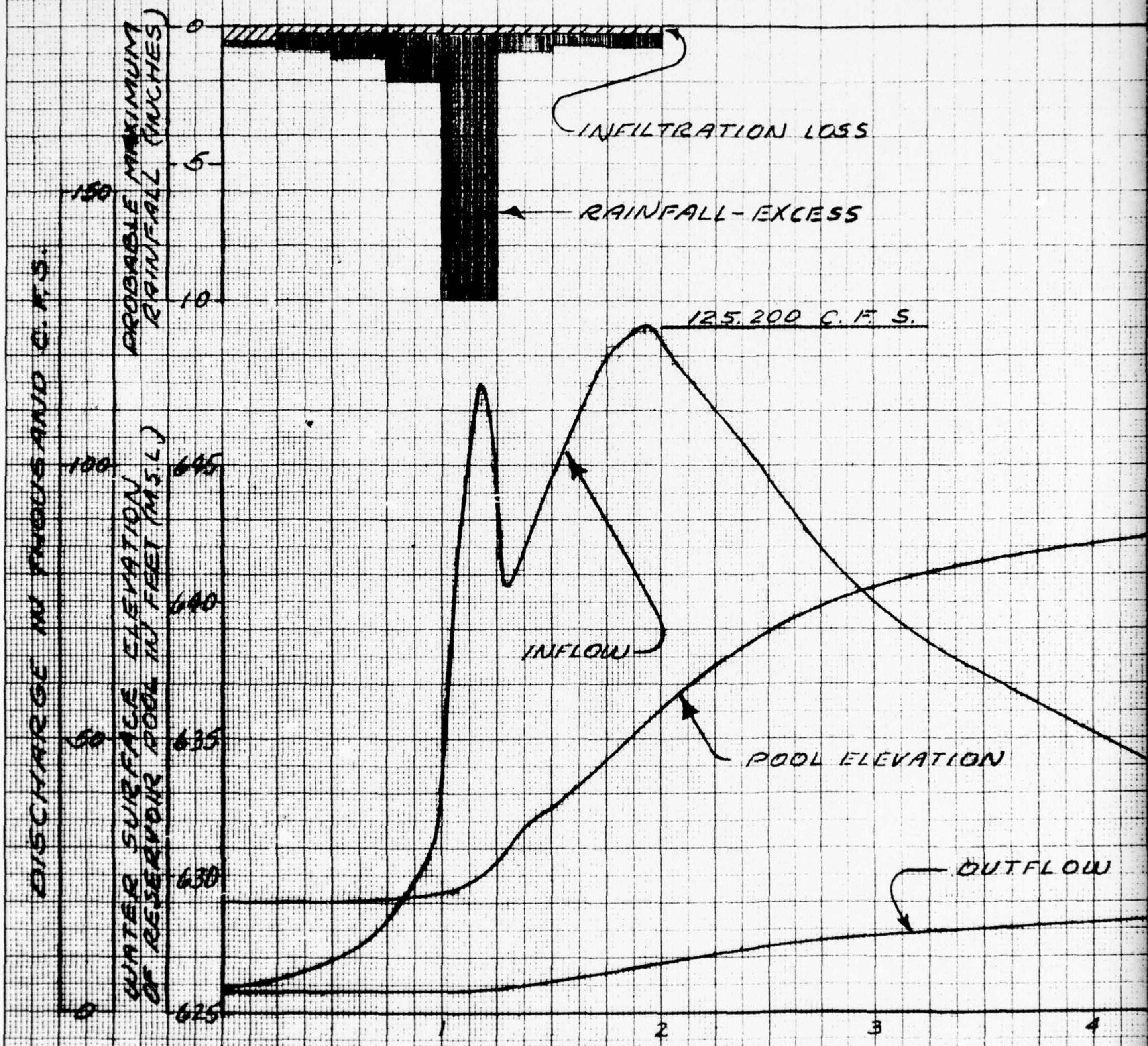
EMBARRASS RIVER, ILLINOIS

PERCENT OF BASIC PROVISIONAL SPILLWAY FLOOD PEAK RESERVOIR ELEVATION-INFLOW-OUTFLOW CURVES

ORLED-H

LOUISVILLE, KY. DEC. 1963

CORPS OF ENGINEERS

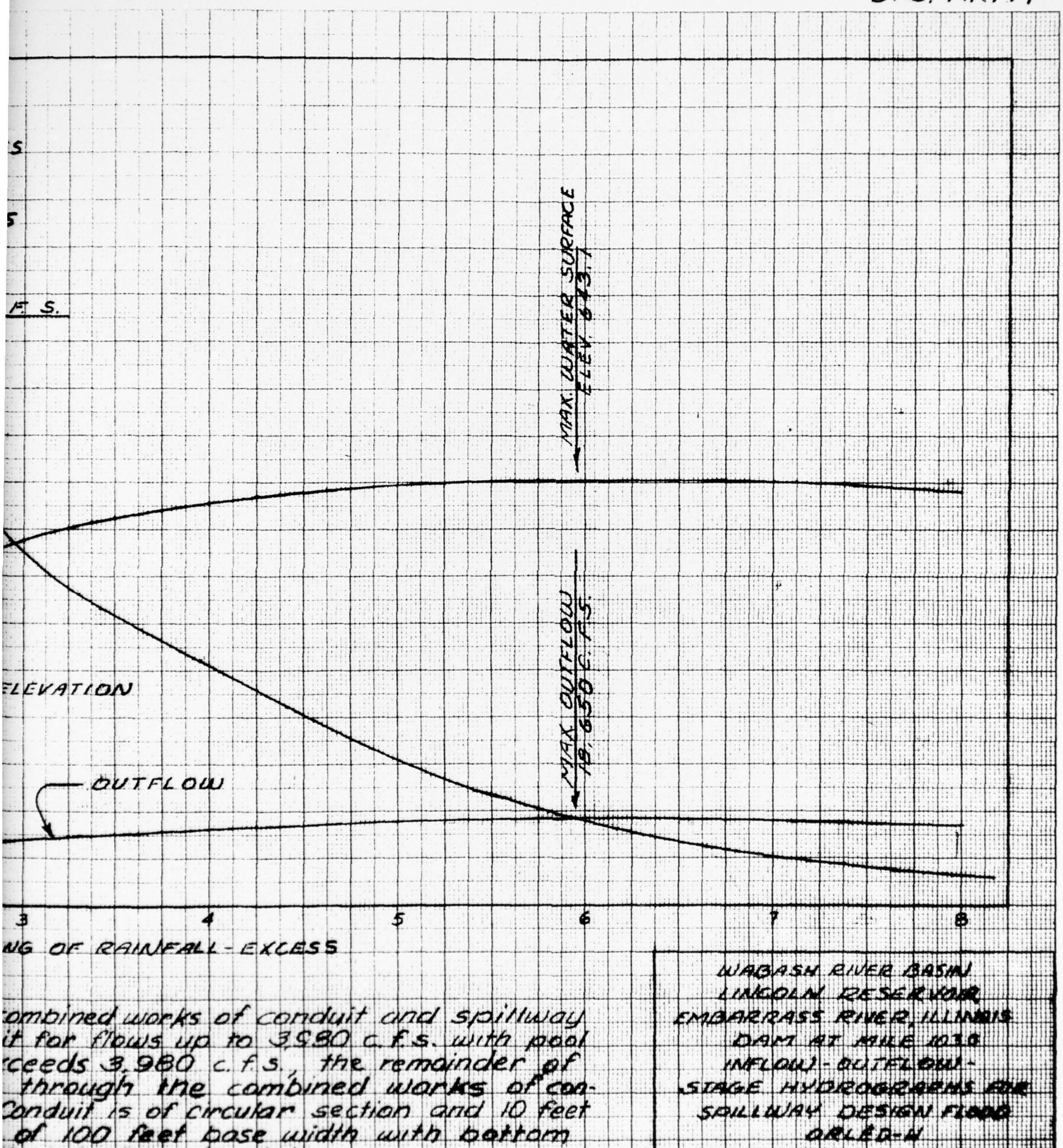


NOTE:

Drainage area - 915 square miles.

Spillway design flood is routed through the combined works of as follows; all inflow is released through conduit for flows up to stationary at elevation 629.0. When inflow exceeds 3,980 c.f. of flood is routed on an uncontrolled basis through the co duit and spillway to a peak pool elevation. Conduit is of circu in diameter. Spillway is an open-cut channel of 100 feet bas at elevation 629.0 and side slopes of 1 vertical to 3 horizon

U. S. ARMY



combined works of conduit and spillway
it for flows up to 3,980 c.f.s. with pool
xceeds 3,980 c.f.s., the remainder of
through the combined works of con-
Conduit is of circular section and 10 feet
of 100 feet base width with bottom
ical to 3 horizontal.

WABASH RIVER BASIN
LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS
DAM AT MILE 103.0
INFLOW-OUTFLOW-
STAGE HYDROGRAPHS FOR
SPILLWAY DESIGN FLOOD
ORLED-H
LOUISVILLE, KY DEC. 19[illegible]

PLATE D-12

CORPS OF ENGINEERS U.S. ARMY

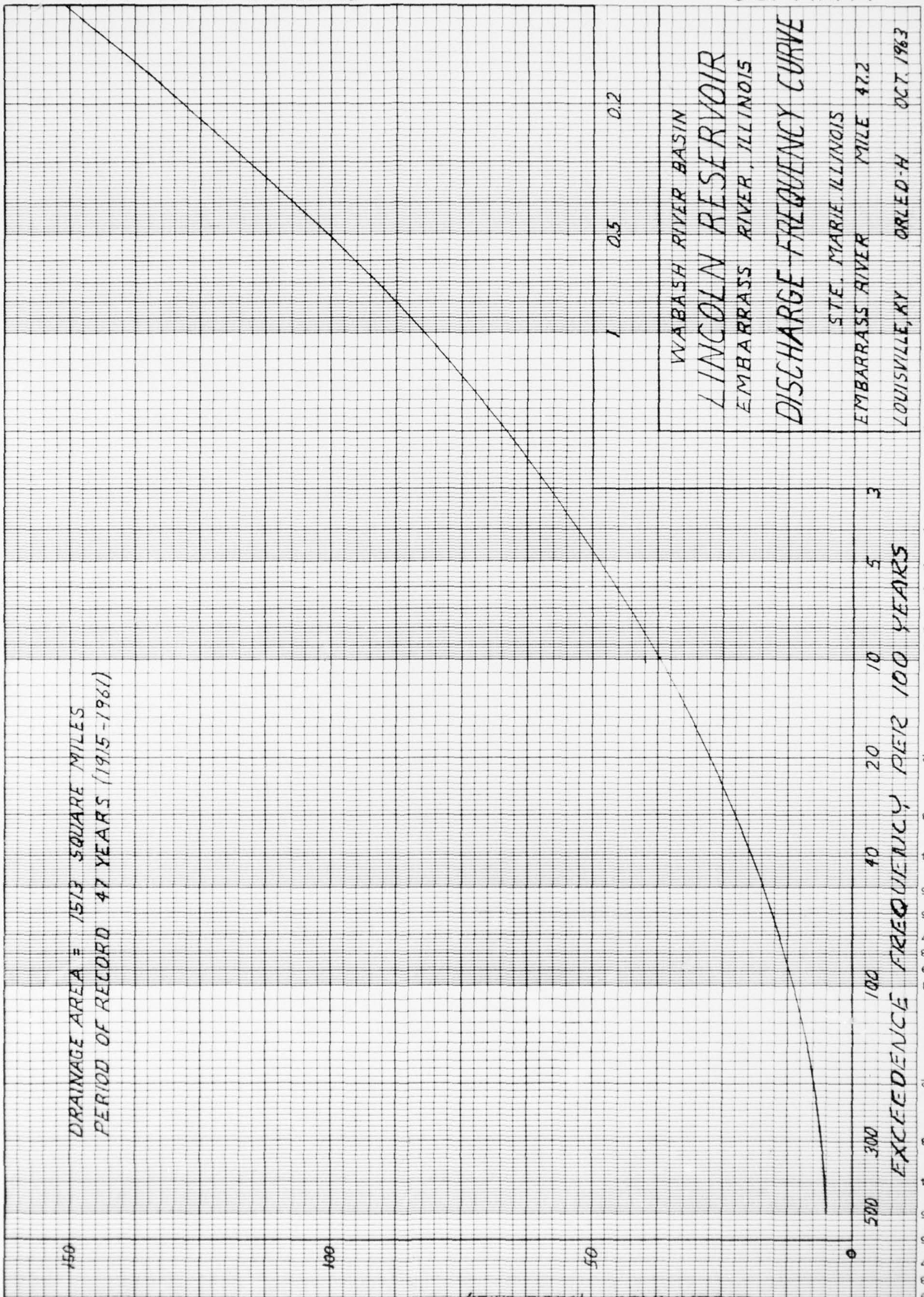
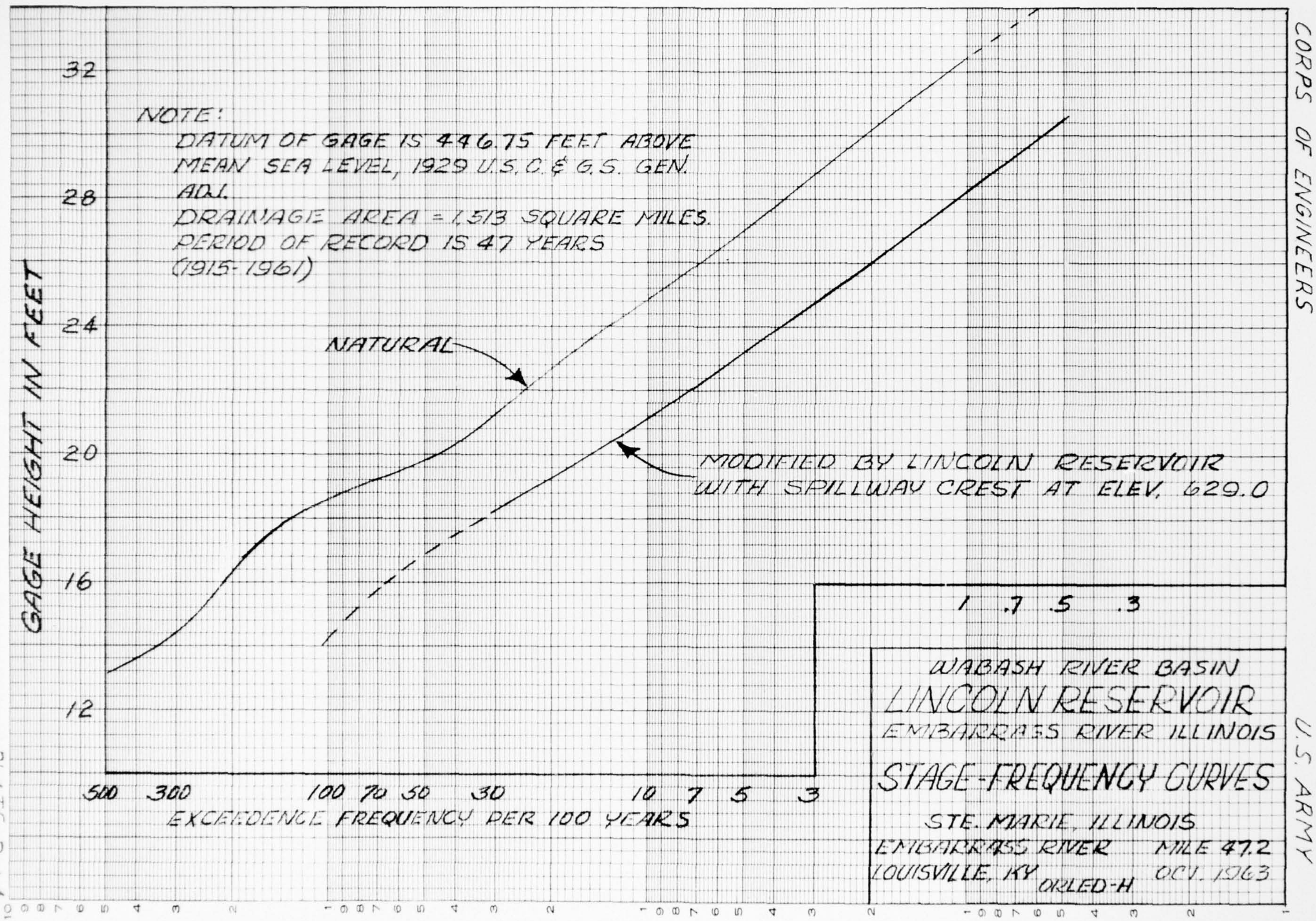
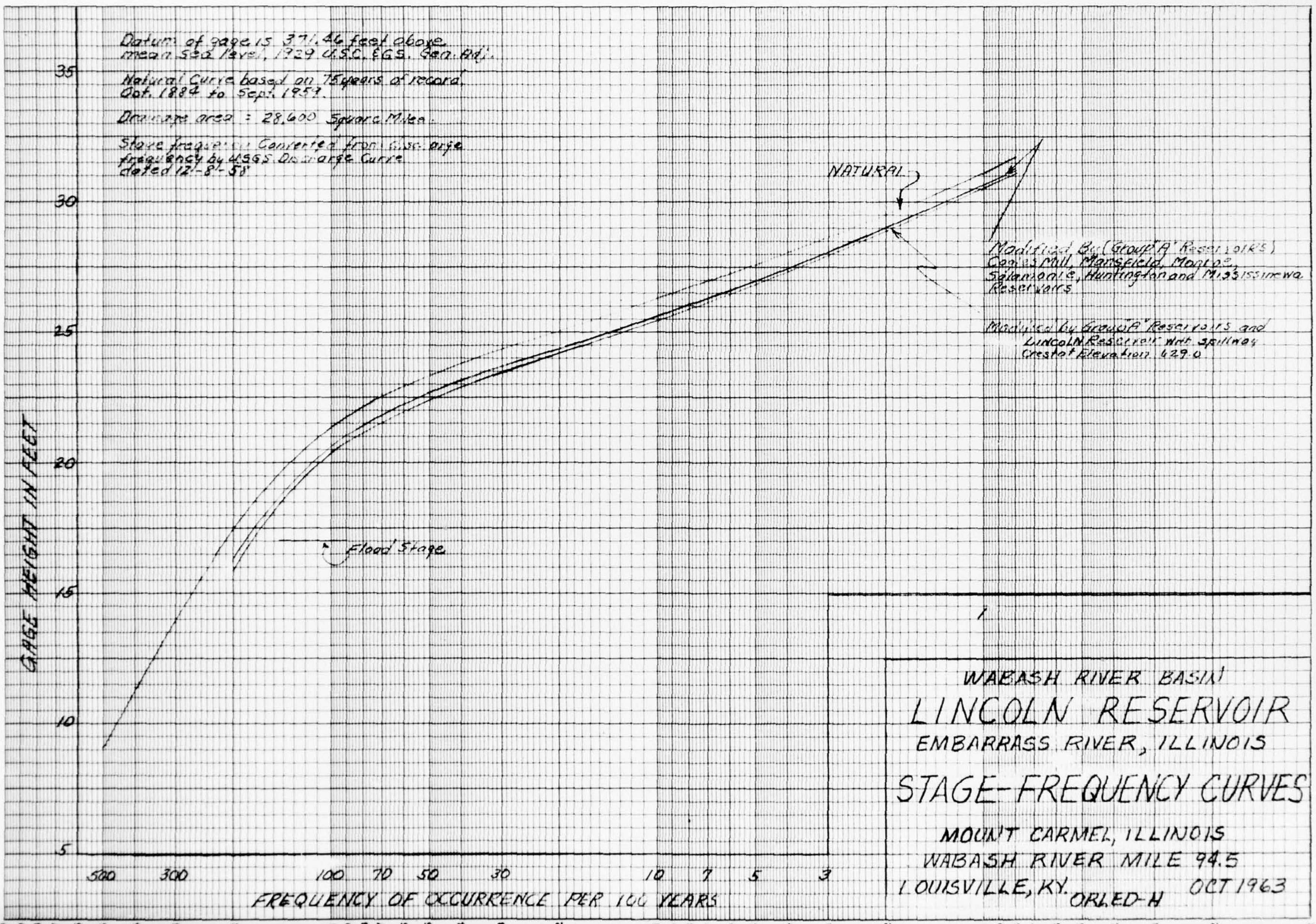
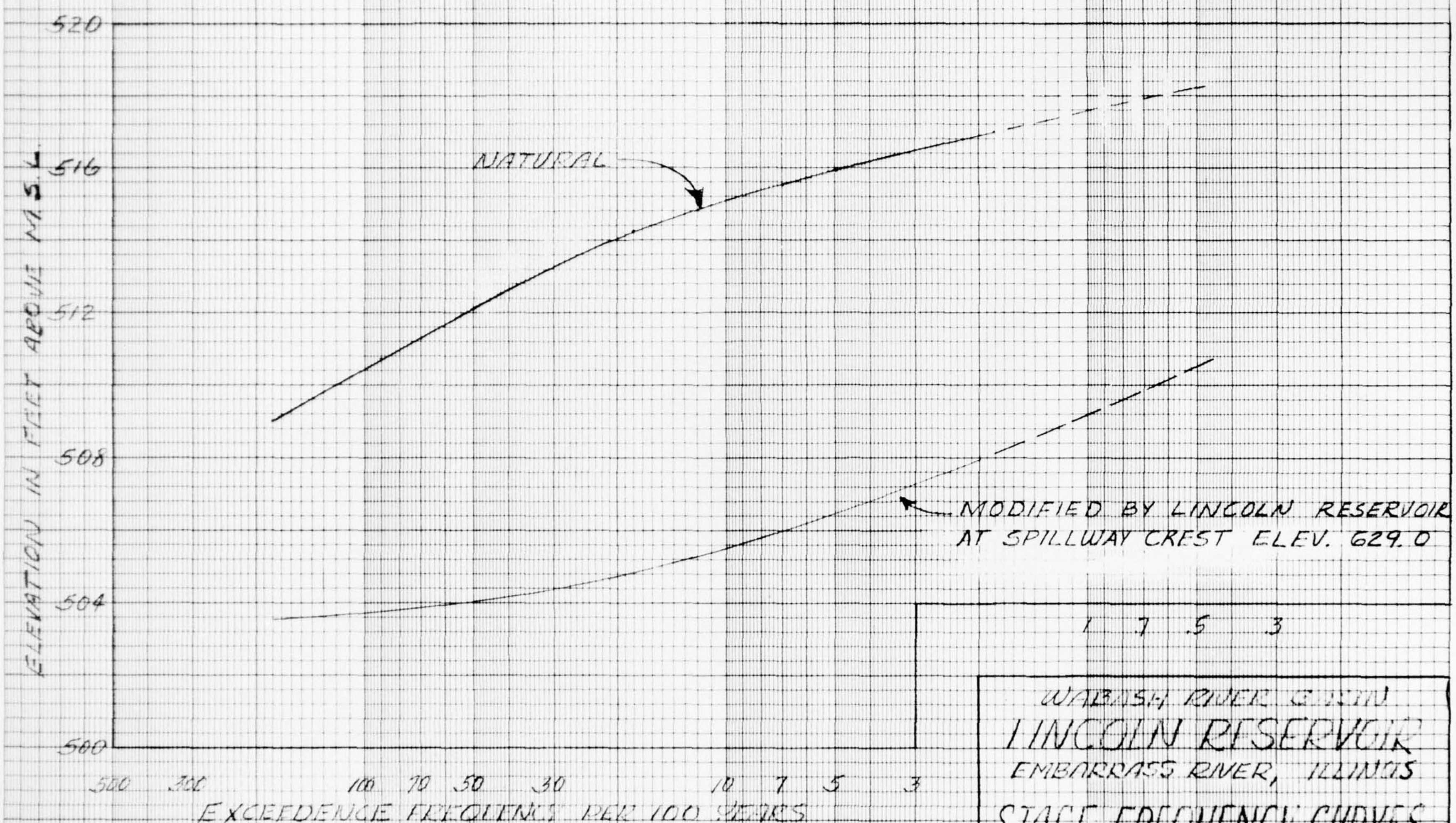


PLATE D-13


CORPS OF ENGINEERS
U.S. ARMY
NOTE:
DATUM OF GAGE IS 446.75 FEET ABOVE MEAN SEA LEVEL, 1929 U.S.C.&G.S. GEN. ADJ.
DRAINAGE AREA = 1,513 SQUARE MILES.
PERIOD OF RECORD IS 47 YEARS (1915-1961)
NATURAL
MODIFIED BY LINCOLN RESERVOIR WITH SPILLWAY CREST AT ELEV. 629.0
GAGE HEIGHT IN FEET
32
28
24
20
16
12
500 300 100 70 50 30 10 7 5 3 1 .7 .5 .3
EXCEEDENCE FREQUENCY PER 100 YEARS
WABASH RIVER BASIN
LINCOLN RESERVOIR
EMBARRASS RIVER ILLINOIS
STAGE-FREQUENCY CURVES
STE. MARIE, ILLINOIS
EMBARRASS RIVER
MILE 47.2
LOUISVILLE, KY
ORLED-H
OCT. 1963


Datum of gage is 371.46 feet above mean sea level, 1929 U.S.C.&G.S. Gen. Adj.
Natural Curve based on 75 years of record. Oct. 1884 to Sept. 1959.
Drainage area = 28,600 Square Miles.
Stage frequency Converted from disc. arge frequency by USGS Discharge Curve dated 12-8-58
NATURAL
Modified By (Group "A" Reservoirs) Cagles Mill, Mansfield, Monroe, Salamonie, Huntington and Mississinewa Reservoirs
Modified by Group "A" Reservoirs and Lincoln Reservoir with spillway Crest of Elevation 429.0
Flood Stage
GAGE HEIGHT IN FEET
35
30
25
20
15
10
5
500
300
100
70
50
30
10
7
5
3
FREQUENCY OF OCCURRENCE PER 100 YEARS
WABASH RIVER BASIN
LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS
STAGE-FREQUENCY CURVES
MOUNT CARMEL, ILLINOIS
WABASH RIVER MILE 94.5
LOUISVILLE, KY. ORLED-H OCT 1963

CORPS OF ENGINEERS U.S. ARMY



NOTE:

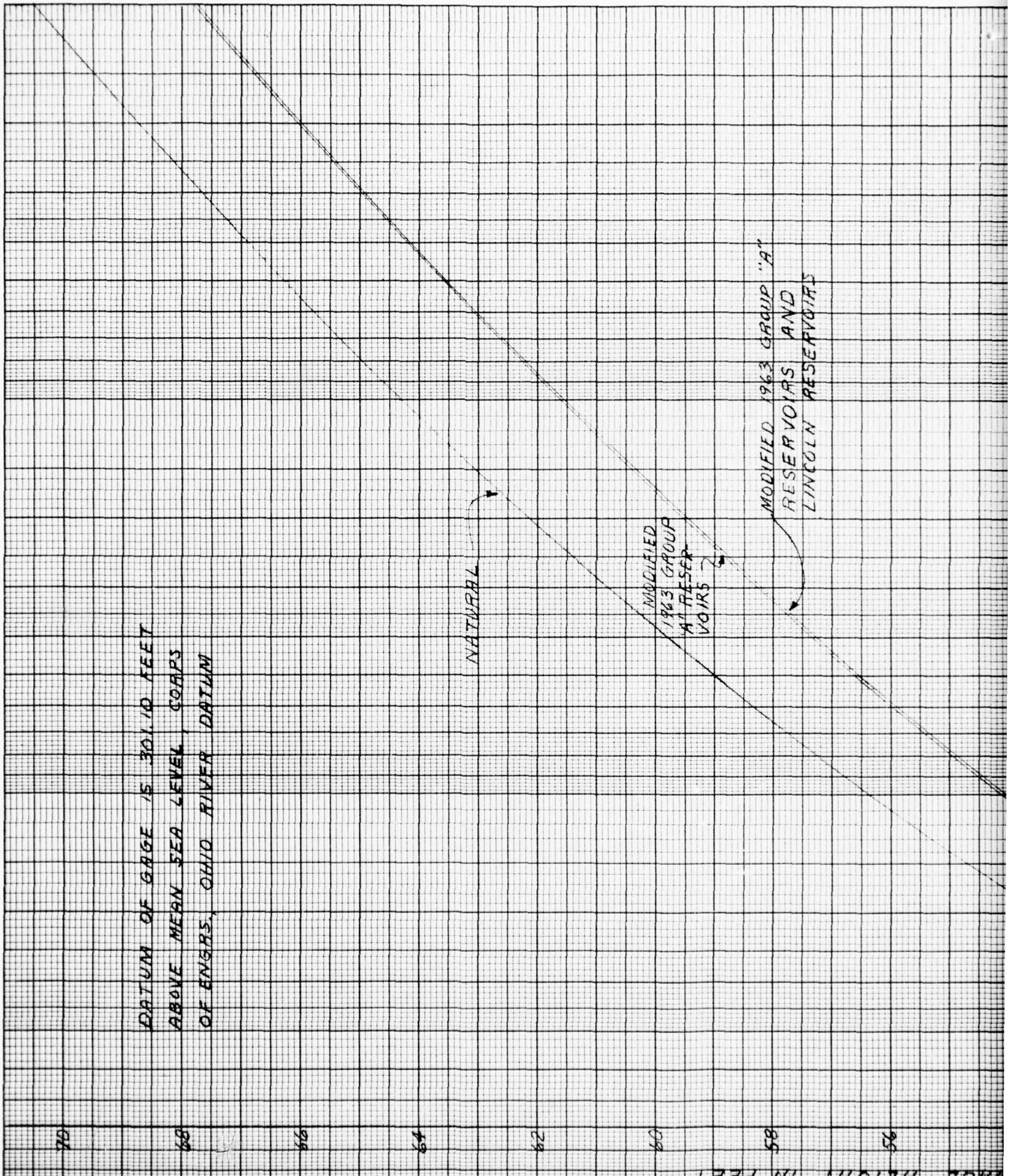
ELEVATIONS REFER TO 1929 U.S.C.&G.S. GEN. ADJ.
DRAINAGE AREA = 1,033 SQUARE MILES

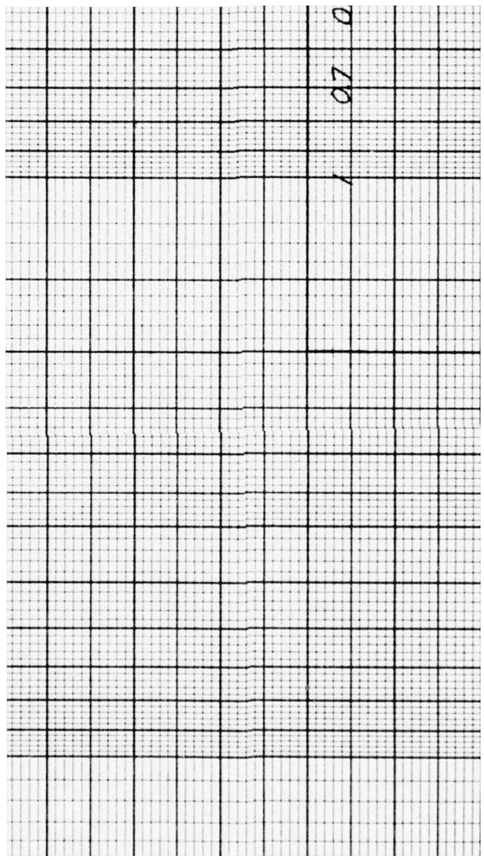
WABASH RIVER BASIN
LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS

STAGE-FREQUENCY CURVES

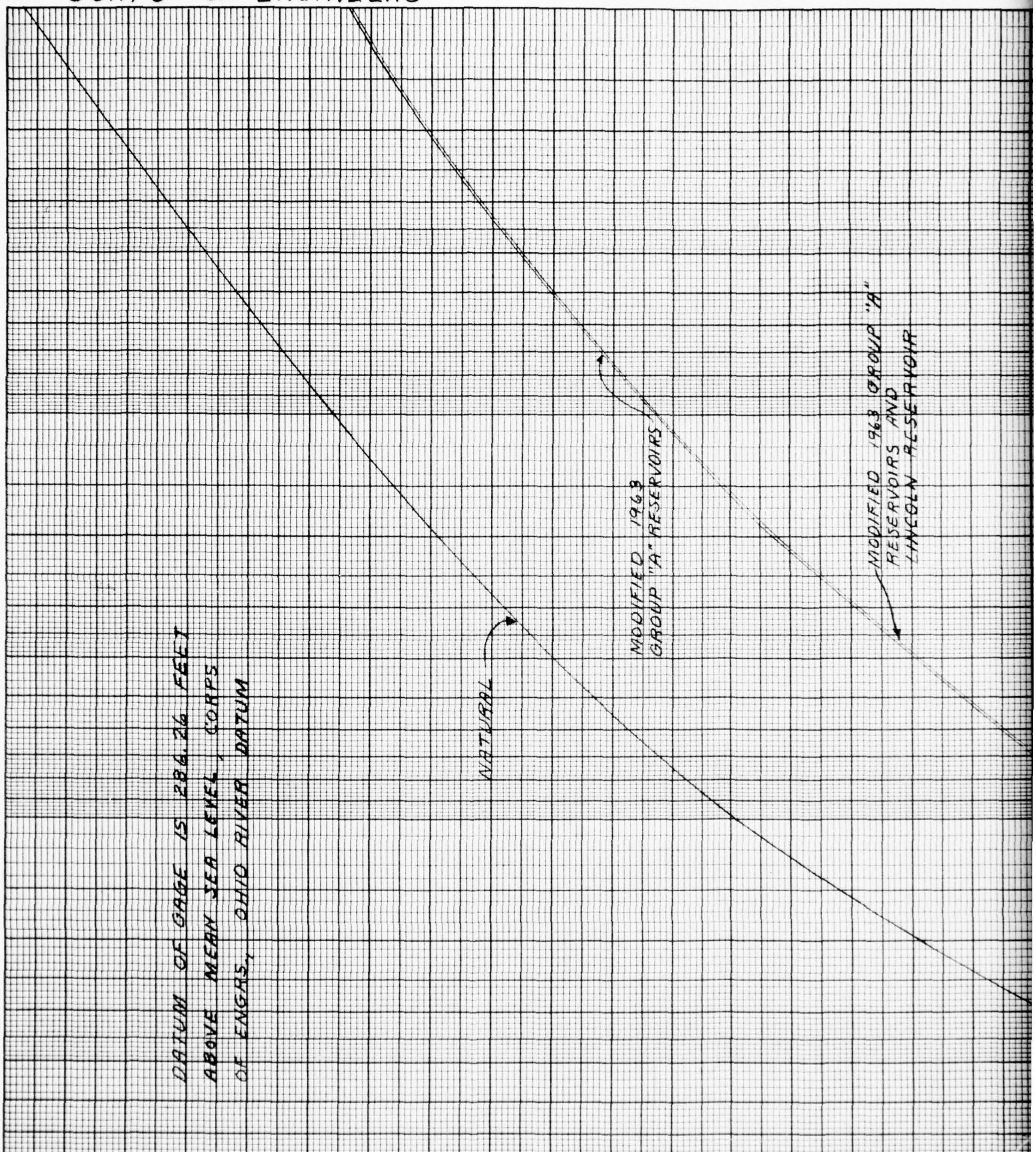
HYPOTHETICAL GAGE
EMBARRASS RIVER MILE 79.9
LOUISVILLE, KY. ORLED-H OCT. 1963

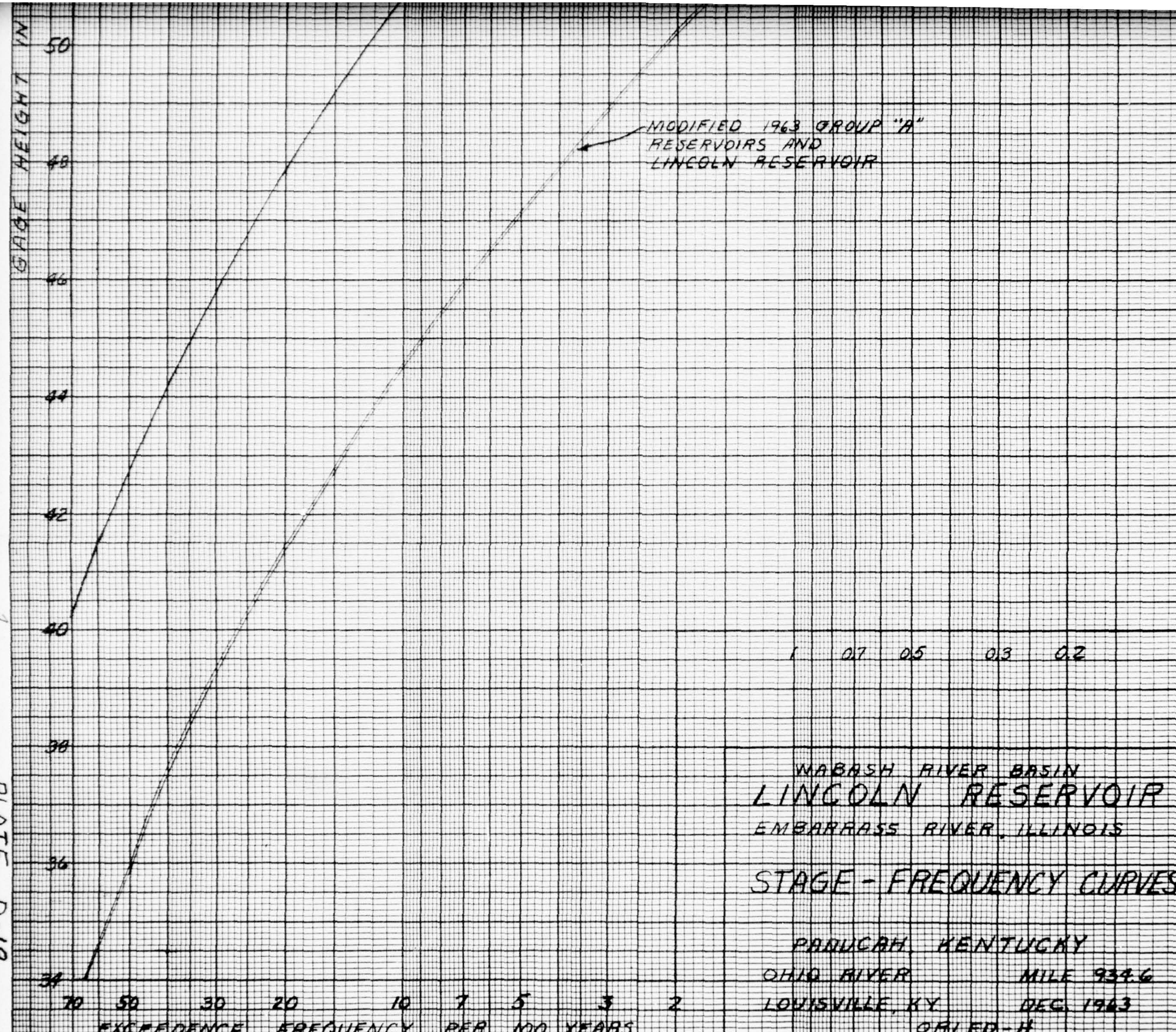
CORPS OF ENGINEERS





CORPS OF ENGINEERS





WABASH RIVER BASIN

LINCOLN RESERVOIR

EMBARRASS RIVER, ILLINOIS

STAGE - FREQUENCY CURVES

PADUCAH, KENTUCKY

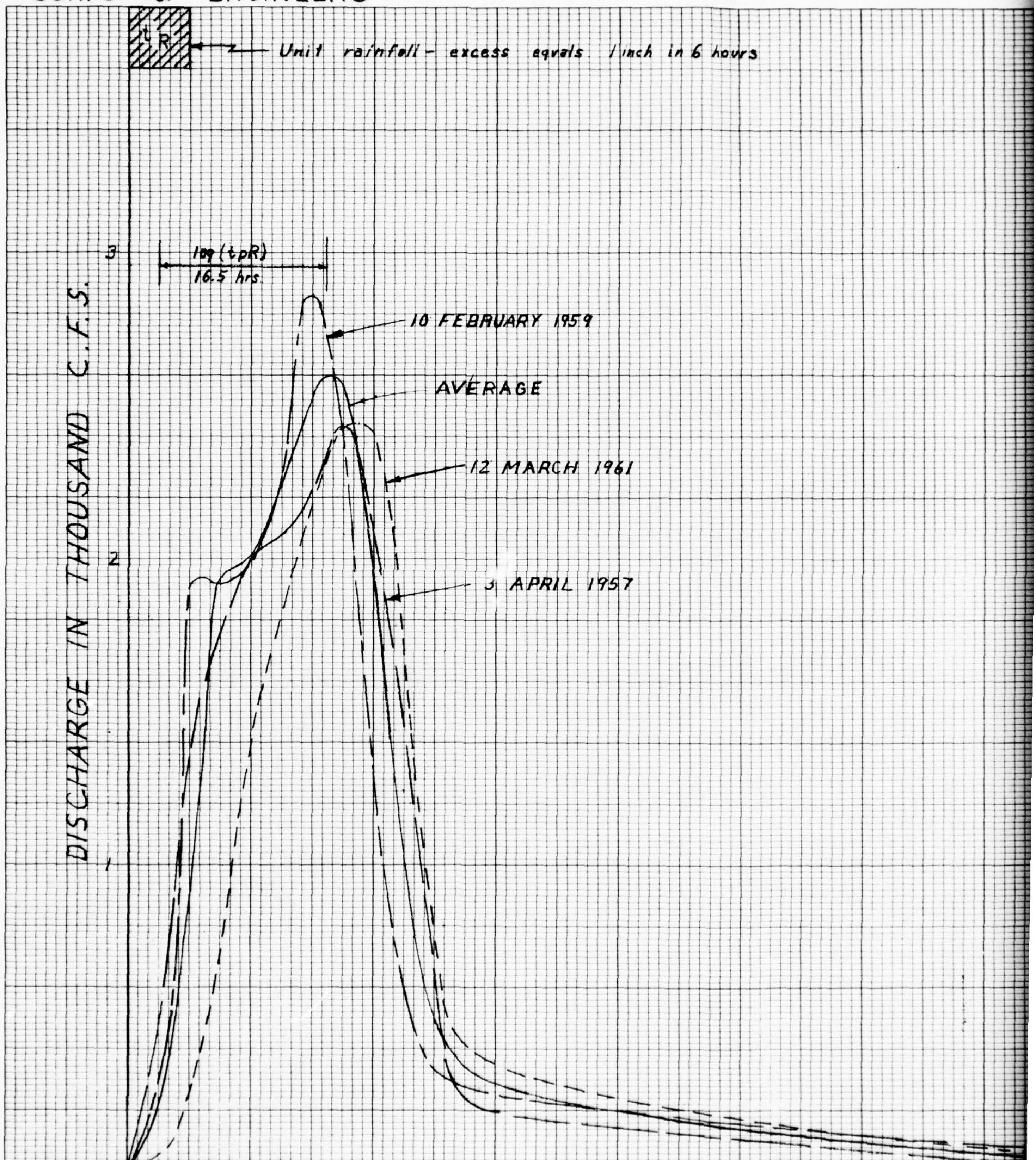
OHIO RIVER MILE 934.6

LOUISVILLE, KY. DEC. 1963

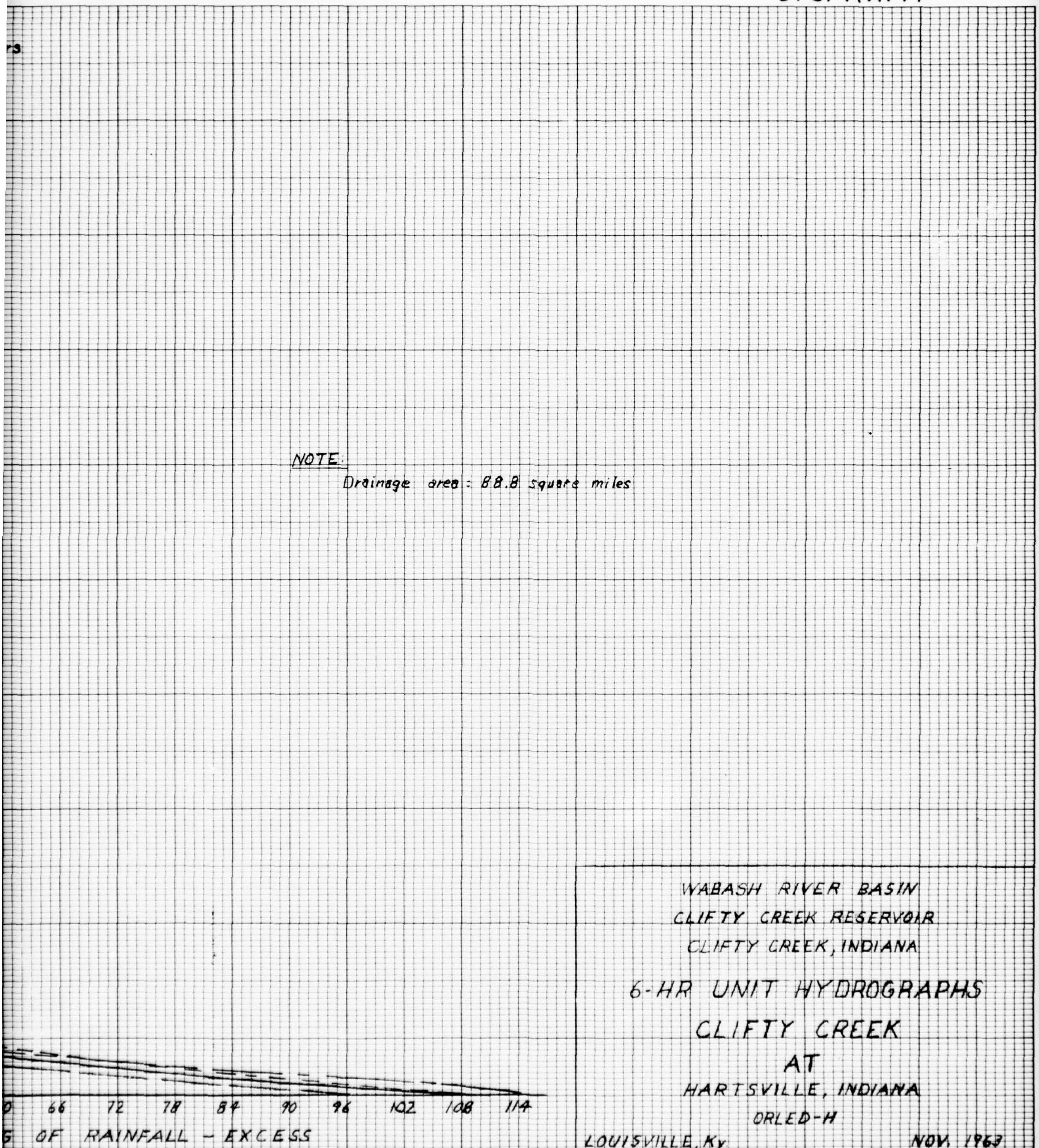
ORLED-H

U.S. ARMY

CORPS OF ENGINEERS



U. S. ARMY



WABASH RIVER BASIN
CLIFTY CREEK RESERVOIR
CLIFTY CREEK, INDIANA

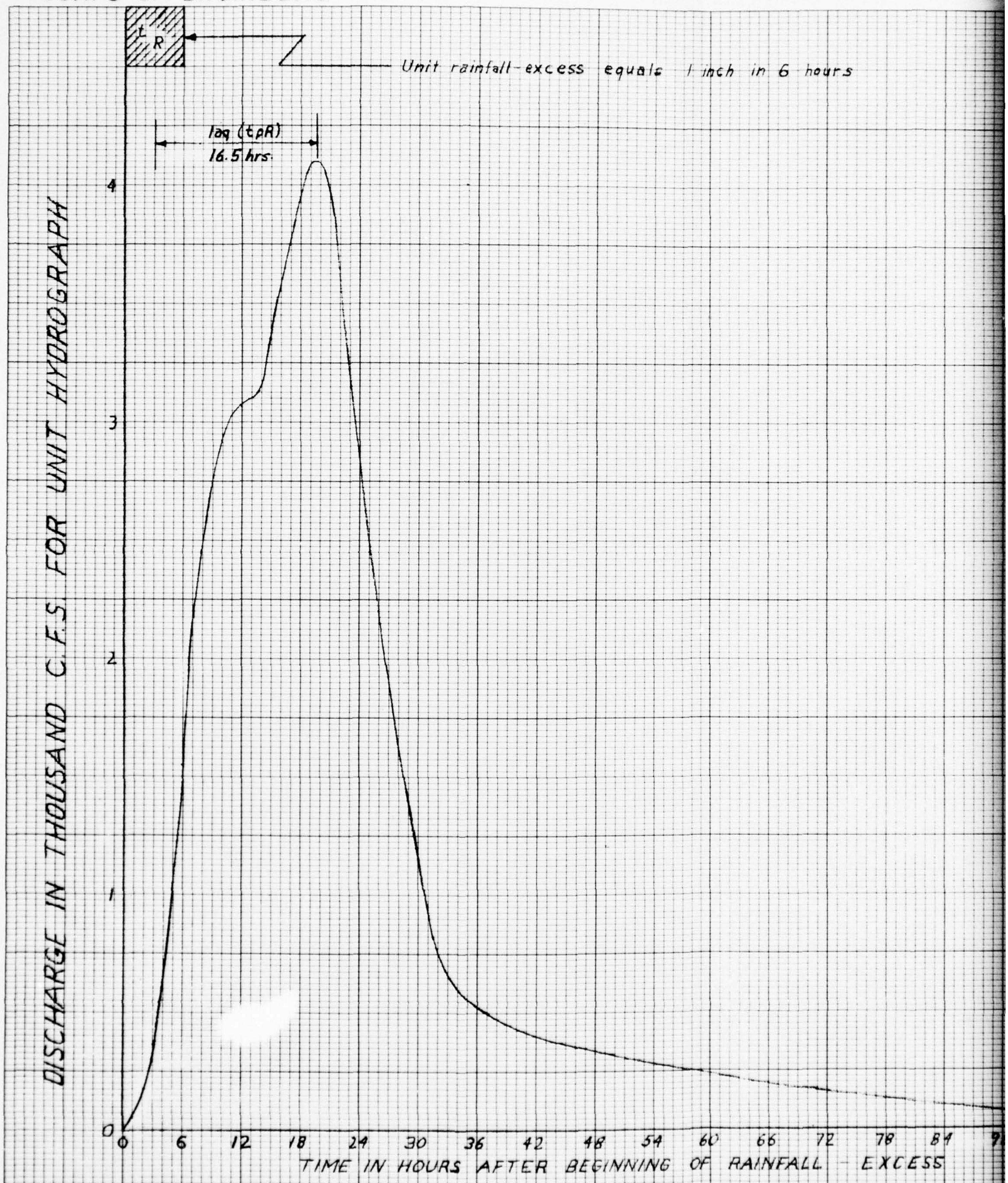
6-HR UNIT HYDROGRAPHS
CLIFTY CREEK
AT
HARTSVILLE, INDIANA

ORLED-H

LOUISVILLE, Ky NOV. 1963

PLATE D-19

CORPS OF ENGINEERS



U.S ARMY

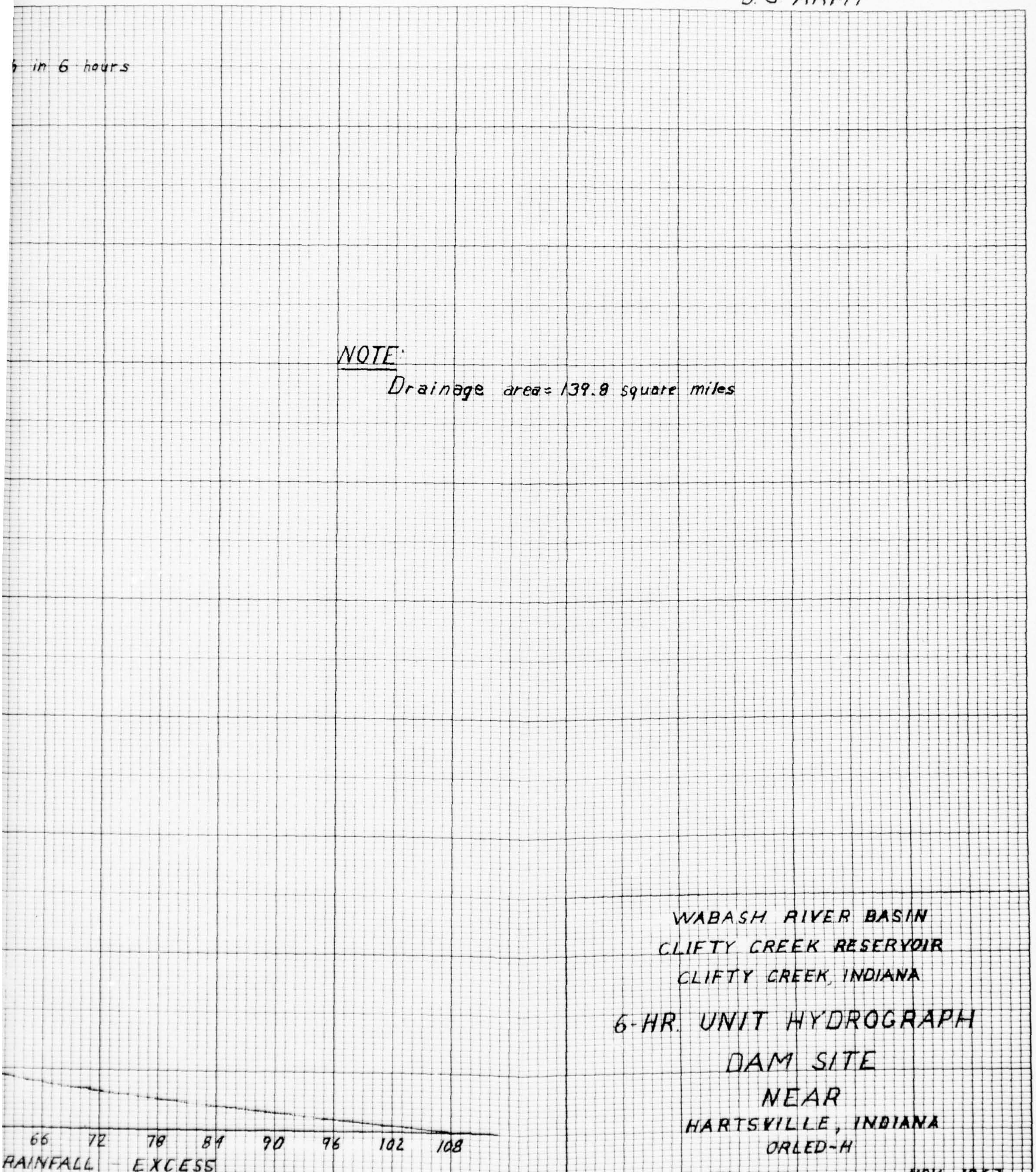
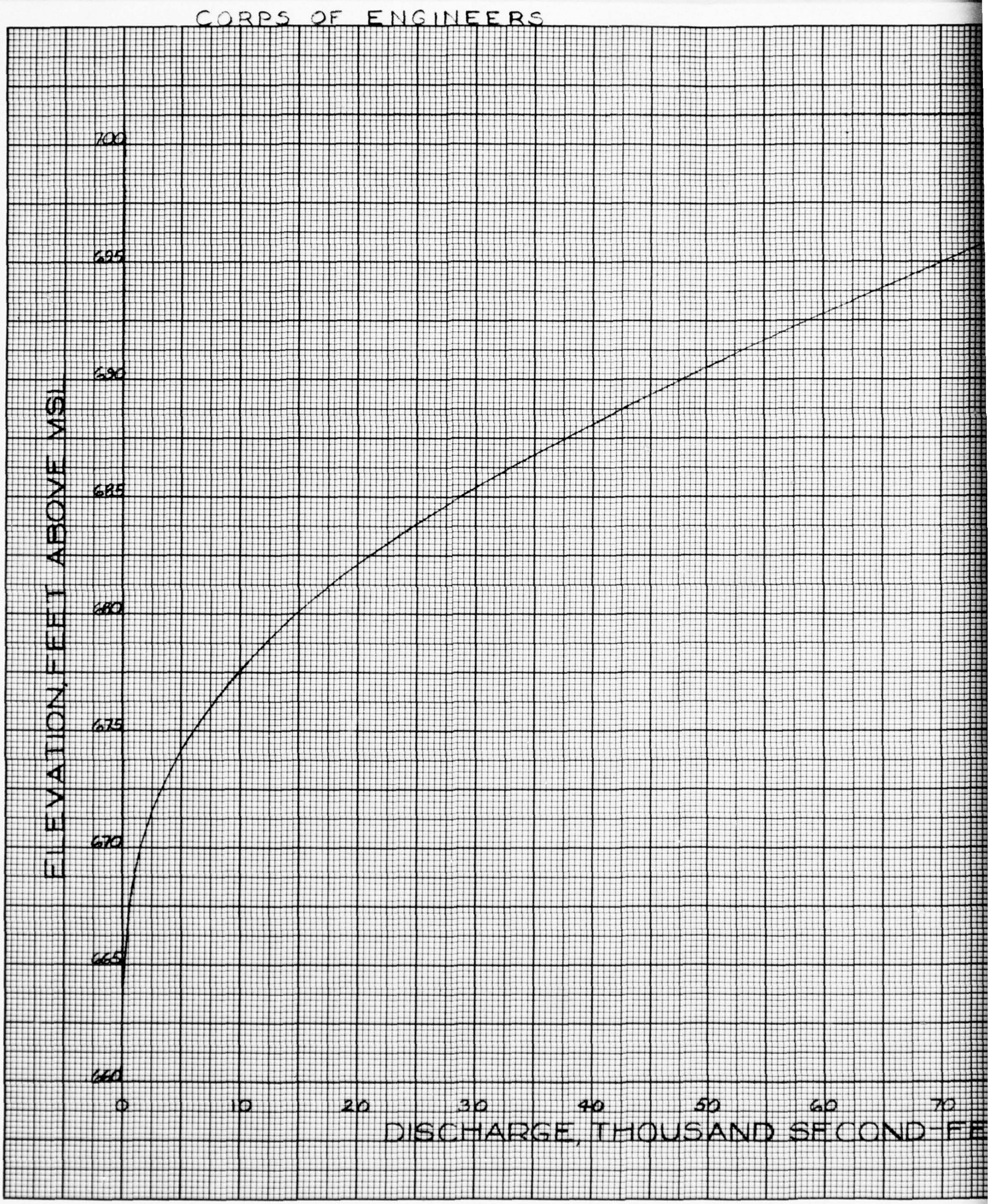
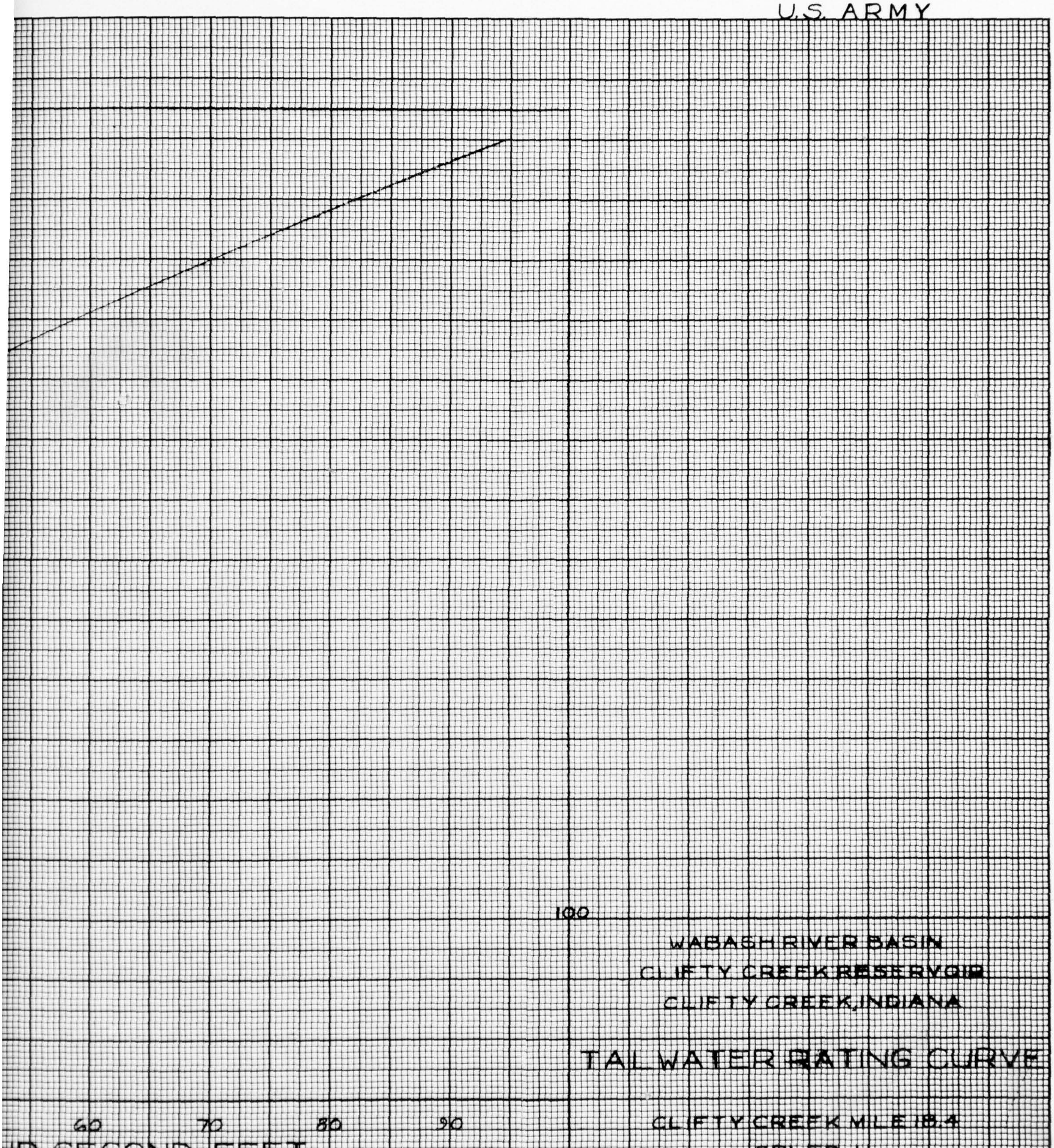


PLATE D-20

2


CORPS OF ENGINEERS
ELEVATION, FEET ABOVE MSL
700
695
690
685
680
675
670
665
660
0
10
20
30
40
50
60
70
DISCHARGE, THOUSAND SECOND-FE

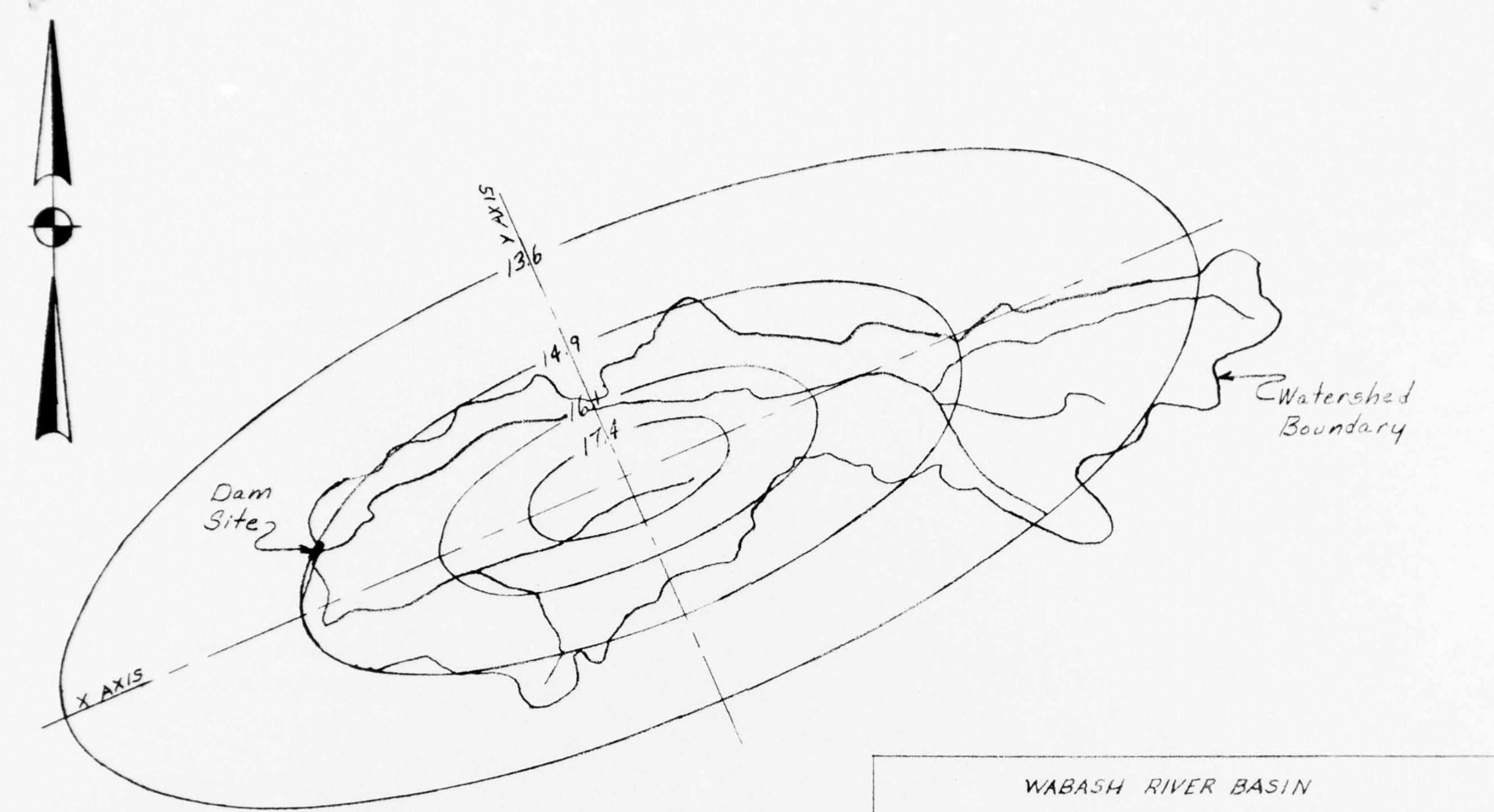
U.S. ARMY



WABASH RIVER BASIN
CLIFTY CREEK RESERVOIR
CLIFTY CREEK, INDIANA

TAILWATER RATING CURVE

CLIFTY CREEK MILE 18.4
ORLED-H
LOUISVILLE, KY. OCTOBER 1963



NOTE:

Project location 39°N., 86°W.
Isohyets represent 96-hour Rainfall amounts
Index Rainfall = 12.4"

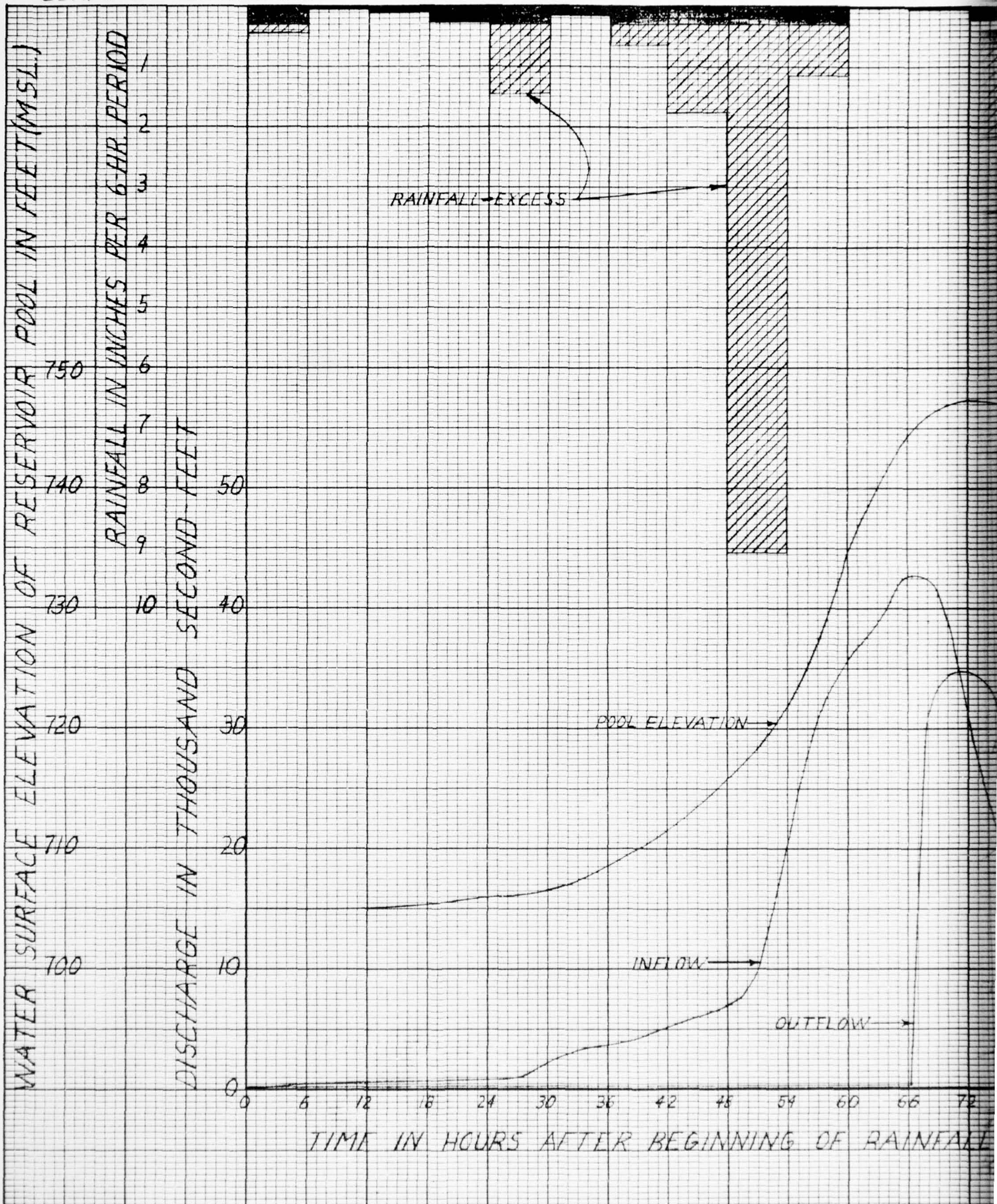
SCALE 1/250,000
20 10 0 MILES 20 40

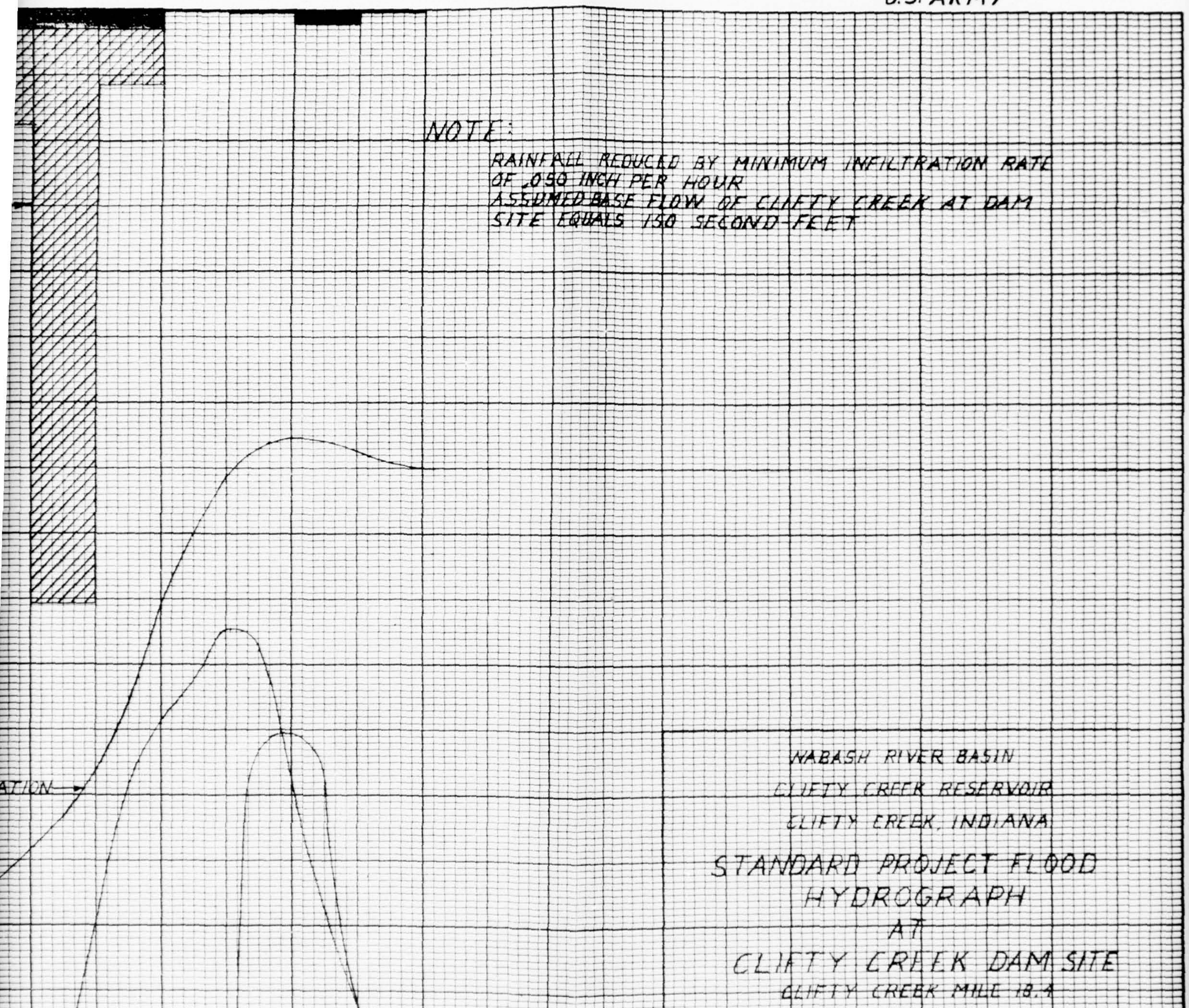
WABASH RIVER BASIN
CLIFTY CREEK RESERVOIR
CLIFTY CREEK, INDIANA

STANDARD PROJECT STORM
ISOHYETAL PATTERN
FOR
CLIFTY CREEK DAM SITE
CLIFTY CREEK MILE 18.4
ORLED-H

LOUISVILLE, KY. DEC. 1963

CORPS OF ENGINEERS



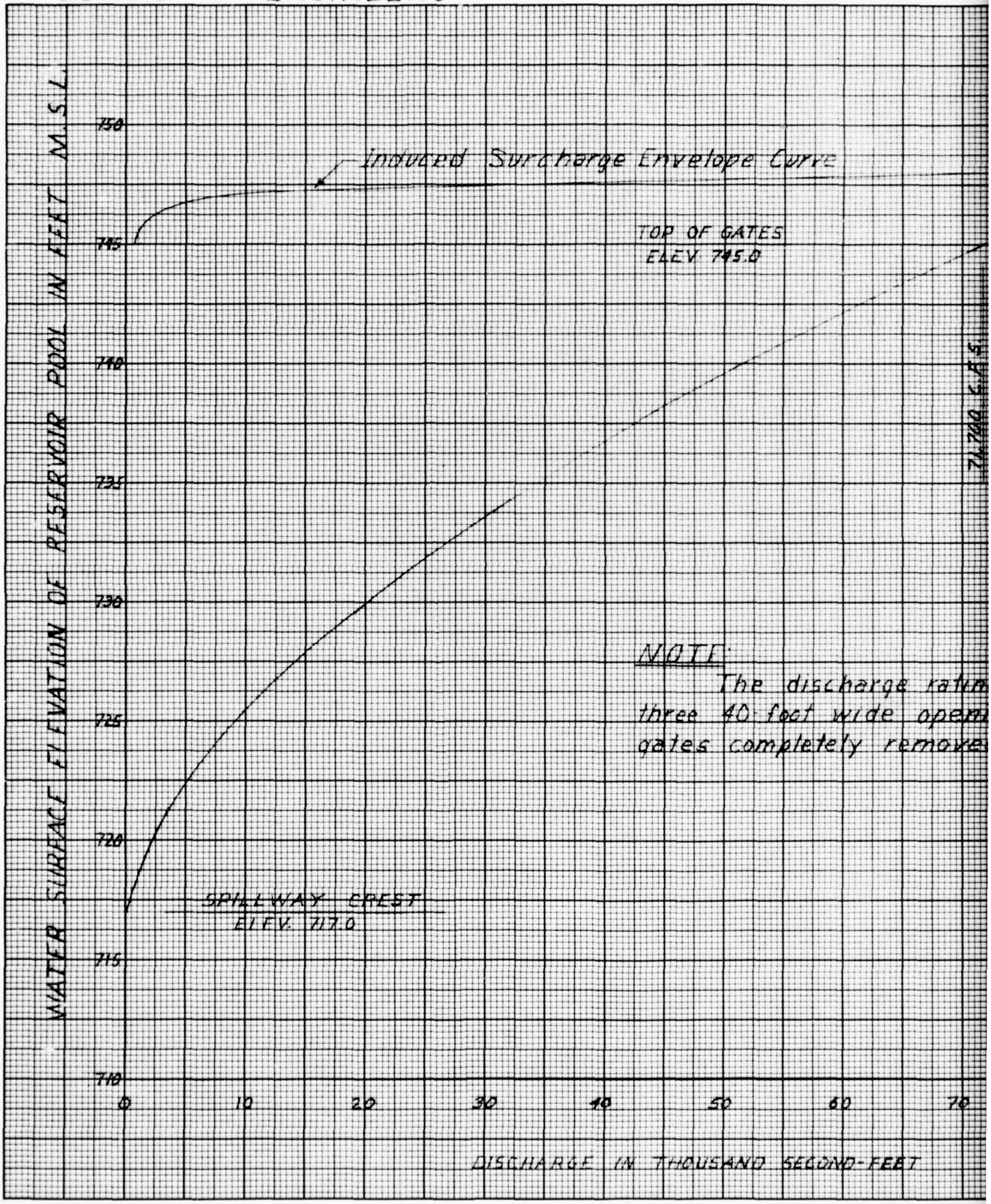


WABASH RIVER BASIN
CLIFTY CREEK RESERVOIR
CLIFTY CREEK, INDIANA

STANDARD PROJECT FLOOD
HYDROGRAPH
AT
CLIFTY CREEK DAM SITE

CLIFTY CREEK MILE 18.4
ORLED-H
LOUISVILLE, KY REVISED FEB., 1964

CORPS OF ENGINEERS



U.S. ARMY

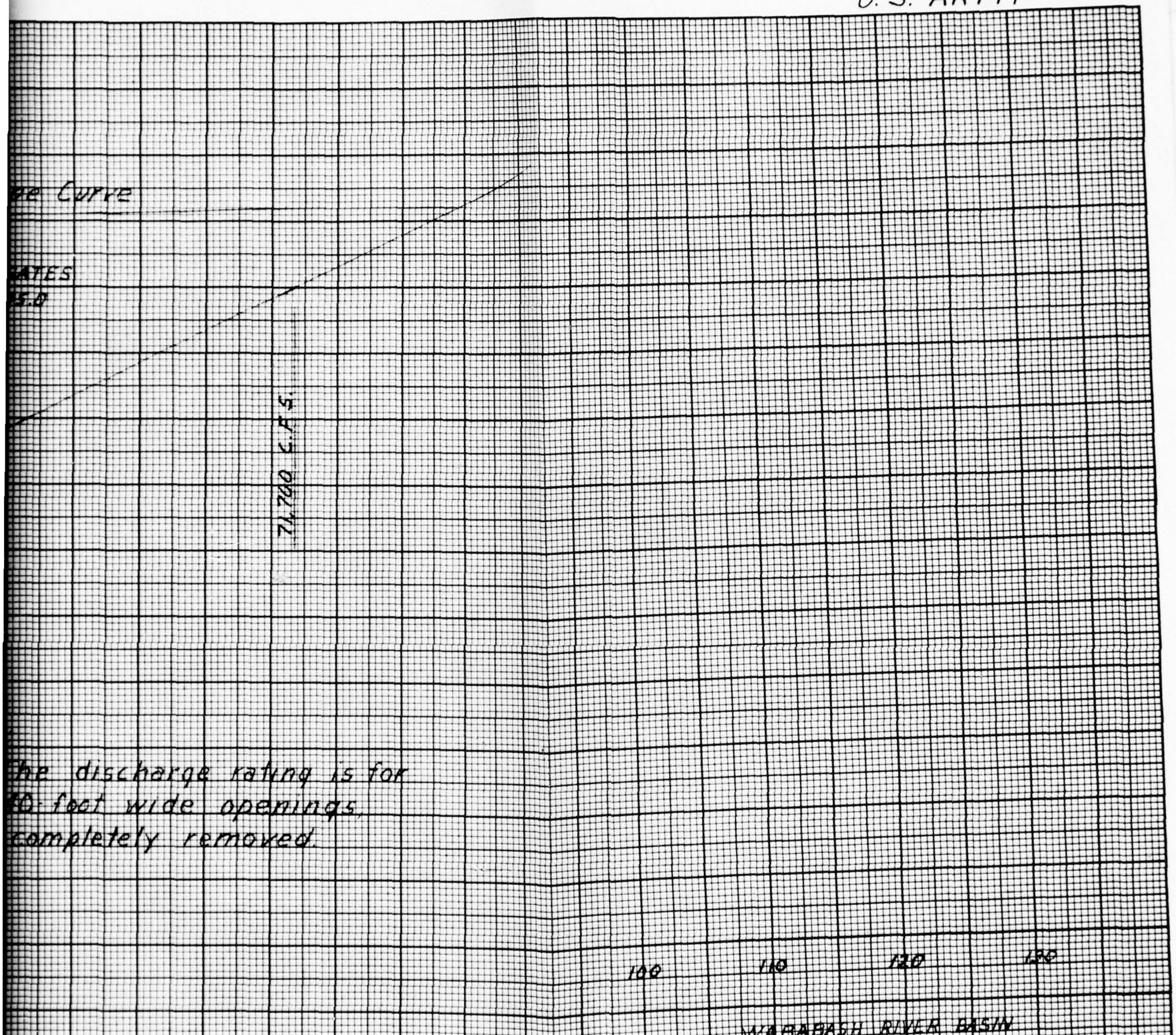
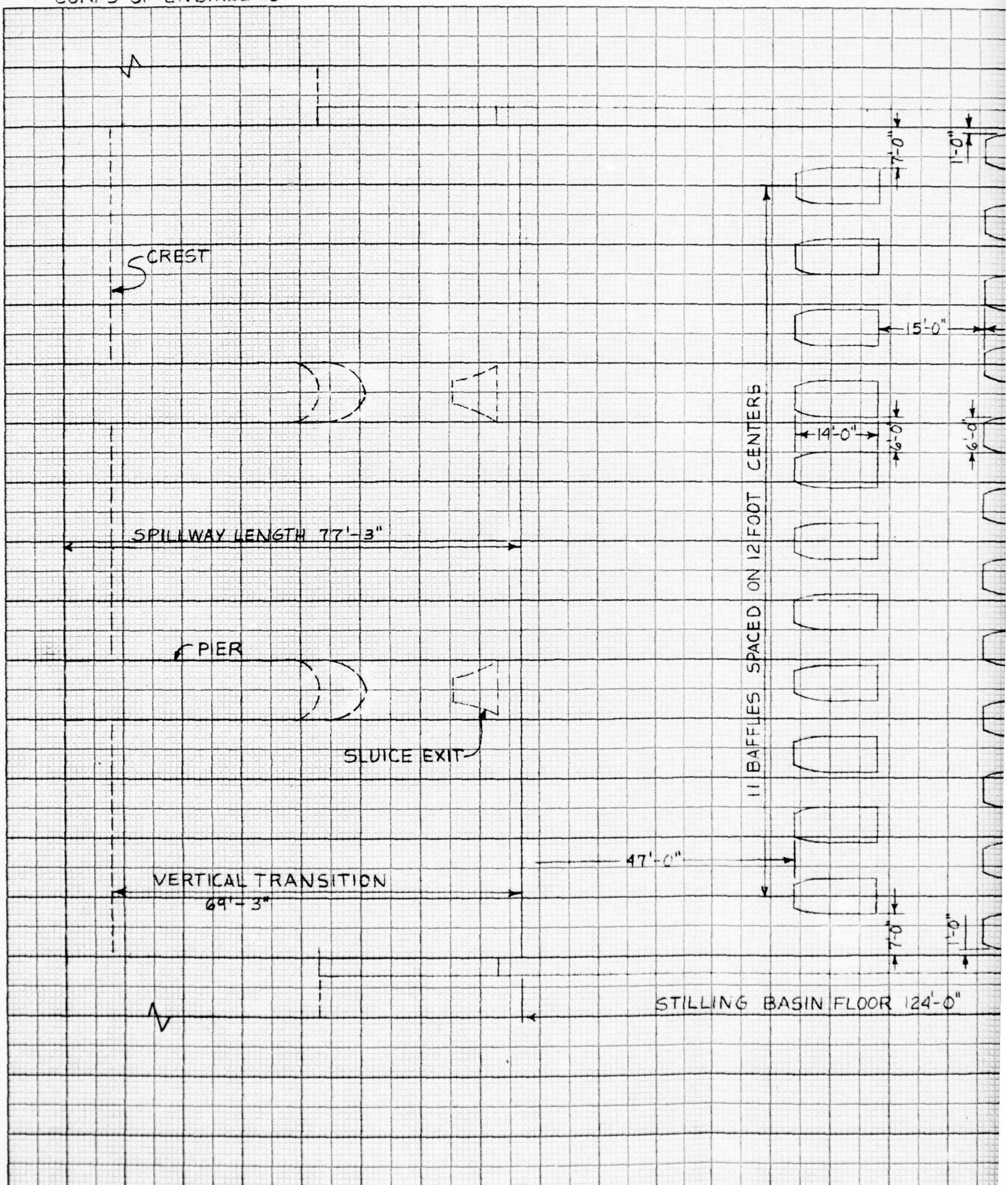


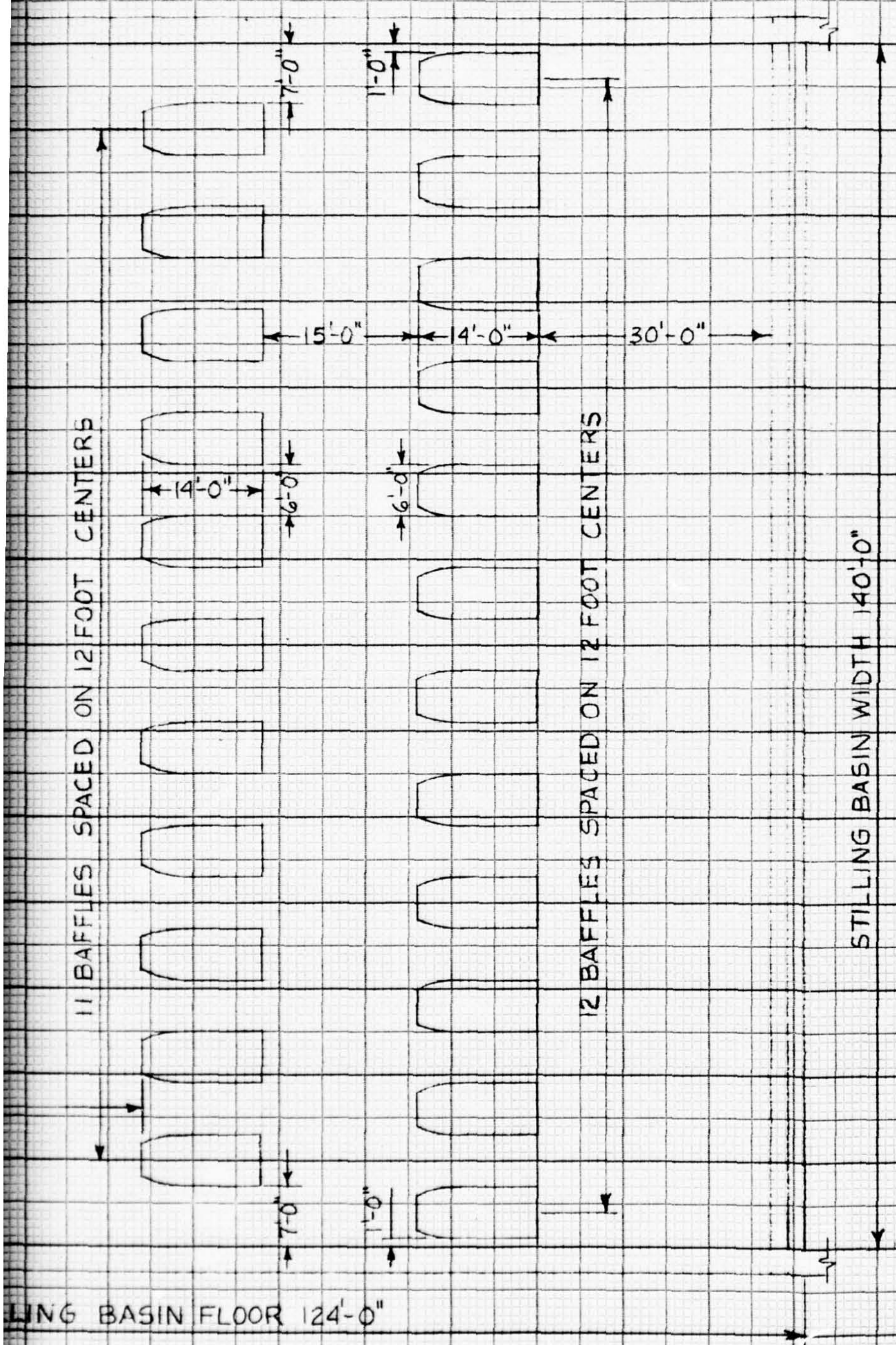
PLATE D-24

2

CORPS OF ENGINEERS



U.S. ARMY



WABASH RIVER BASIN
CLIFTY CREEK RESERVOIR
CLIFTY CREEK, INDIANA

PLAN
OF
STILLING BASIN

SCALE: 1" = 20'

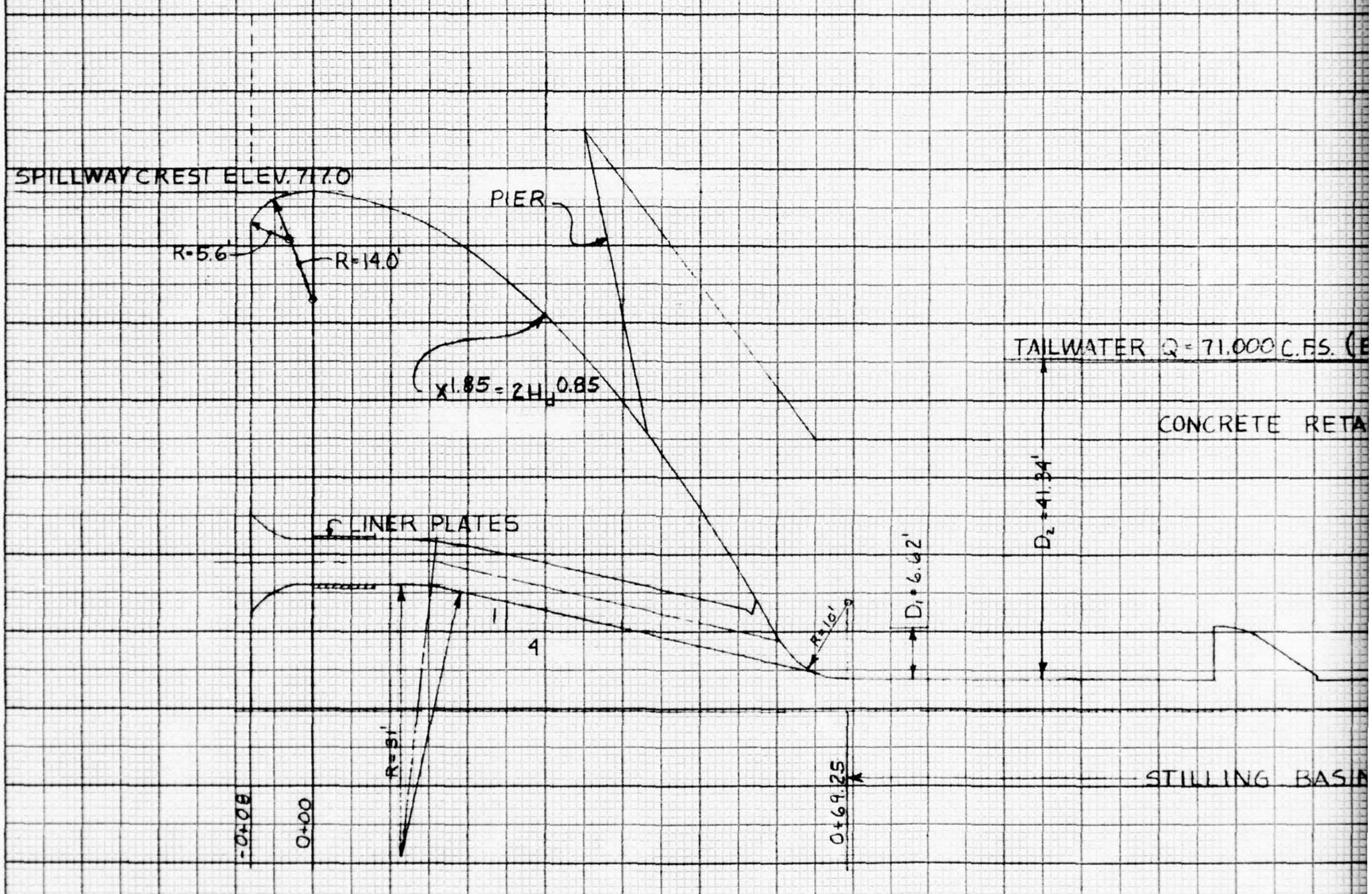
ORLED-H

LOUISVILLE, KY. DEC. 1963

PLATE D-25

2

CORPS OF ENGINEERS

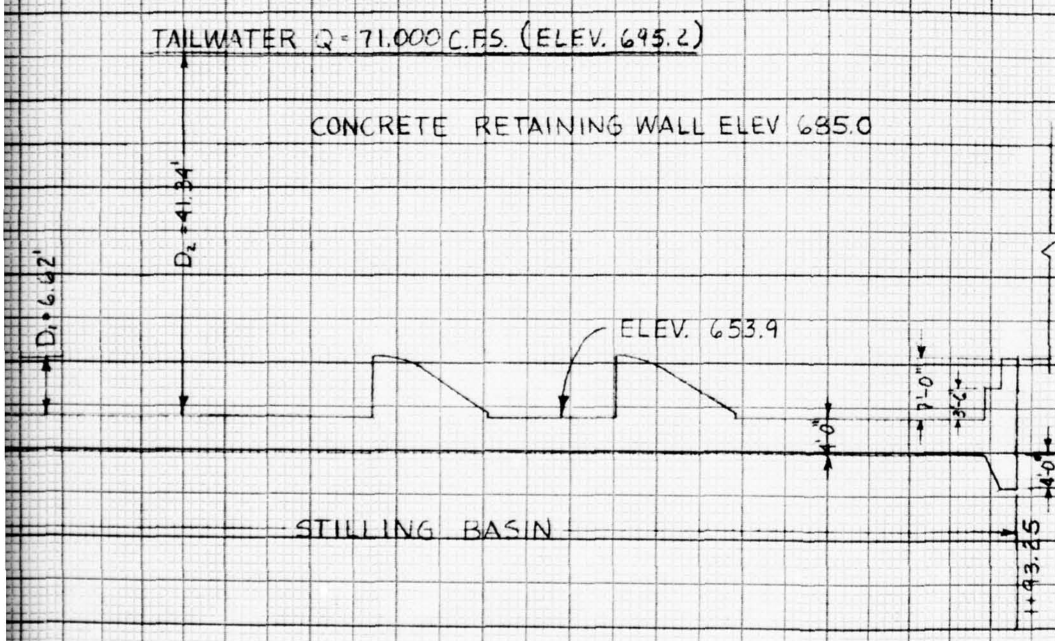


SECTION OF SPILLWAY AND STILLING BASIN

NOTE:

The stilling basin is designed on a basis of pool elevation 744.8, at spillway crest, for a release of 71,000 c.f.s., which requires the 3 tainter gates completely open. A width of 140.0 feet remains constant throughout entire length of stilling basin.

U.S. ARMY



AY AND STILLING BASIN

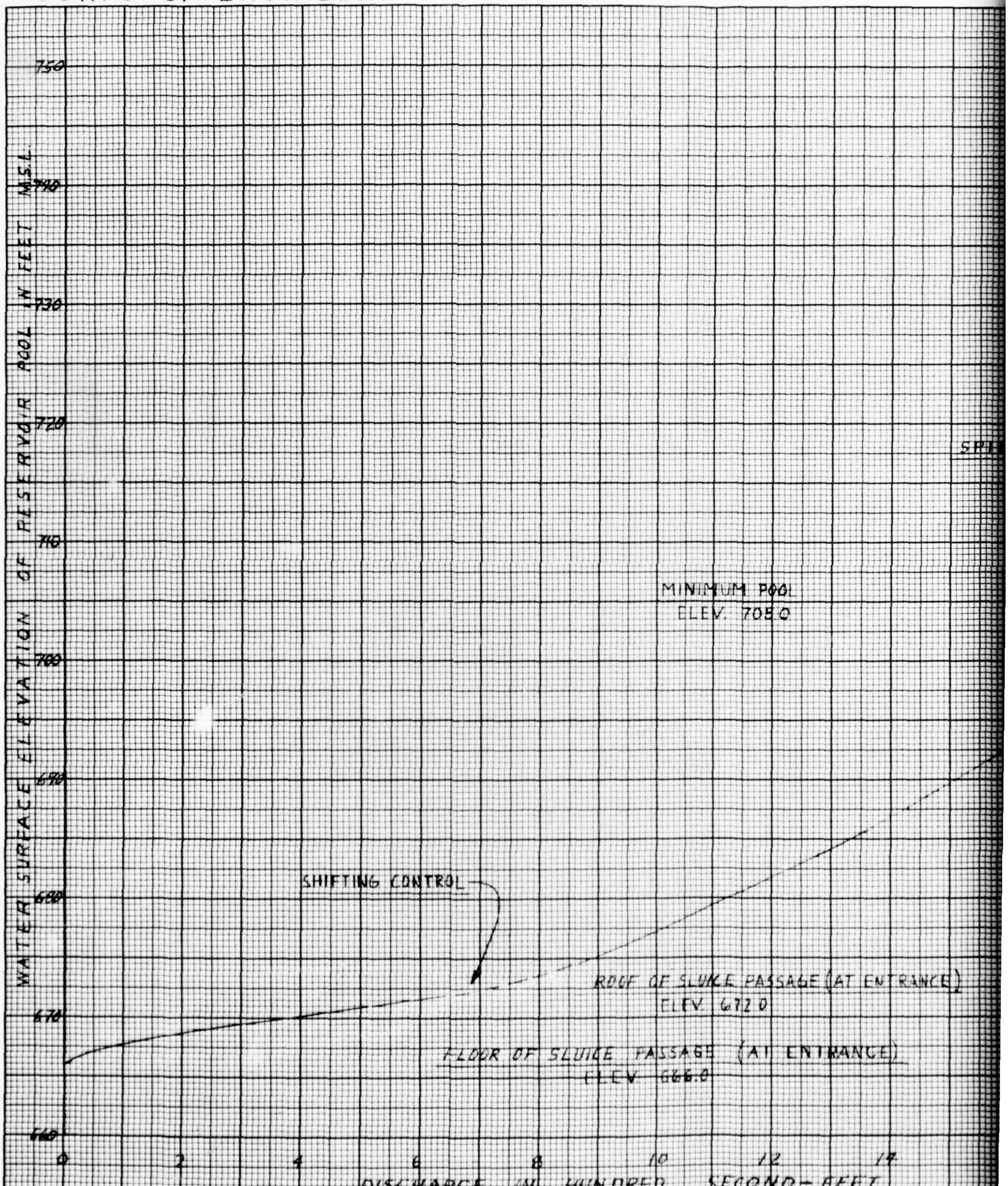
evation 744.8, at spillway crest,
3 tainter gates completely open.
t entire length of stilling basin.

WABASH RIVER BASIN
CLIFTY CREEK RESERVOIR
CLIFTY CREEK, INDIANA
HYDRAULIC ELEMENTS
OF
STILLING BASIN
SCALE: 1" = 20'
ORLED-H
LOUISVILLE, KY. DEC. 1963

PLATE D-26

2

CORPS OF ENGINEERS



U.S. ARMY

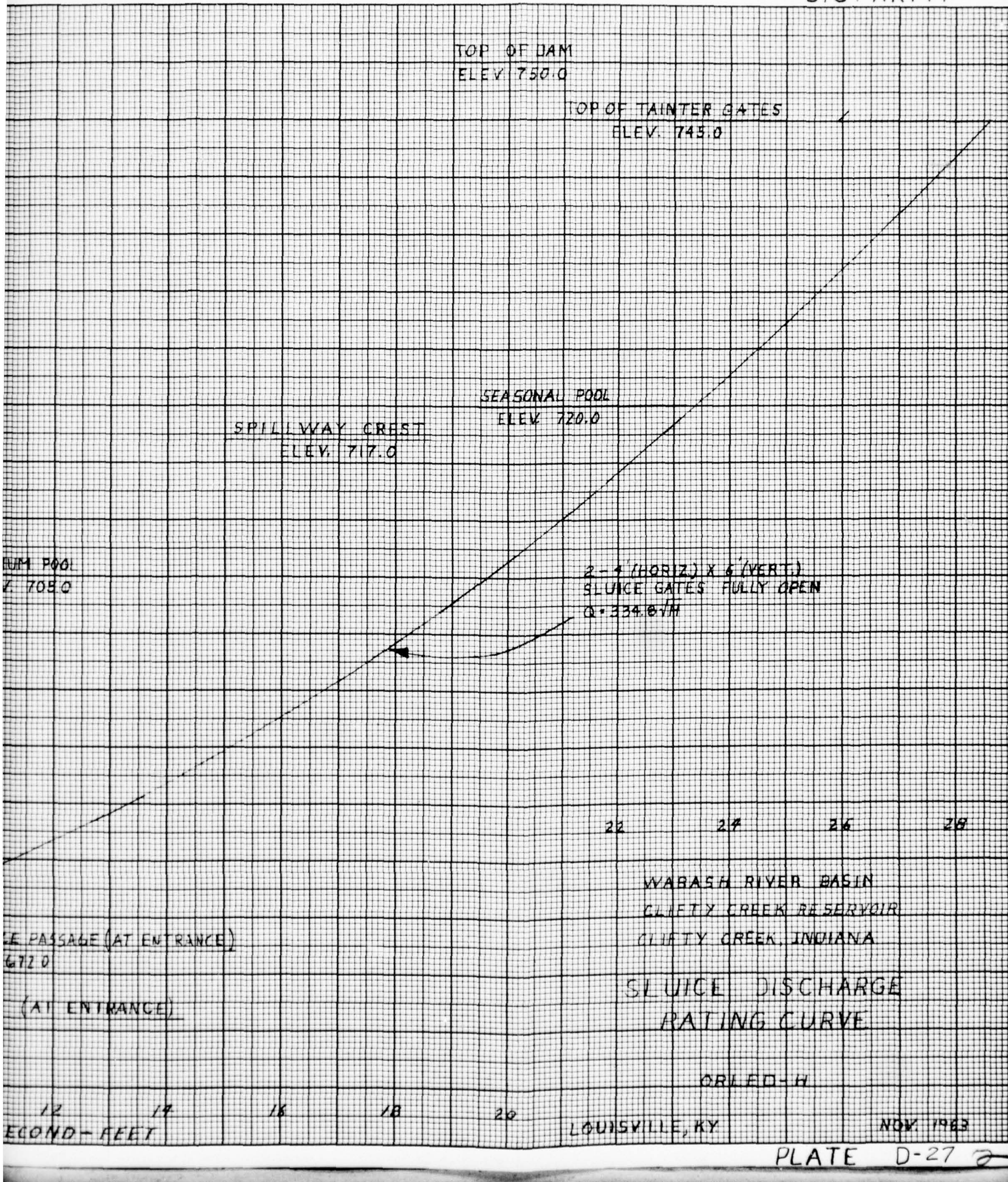
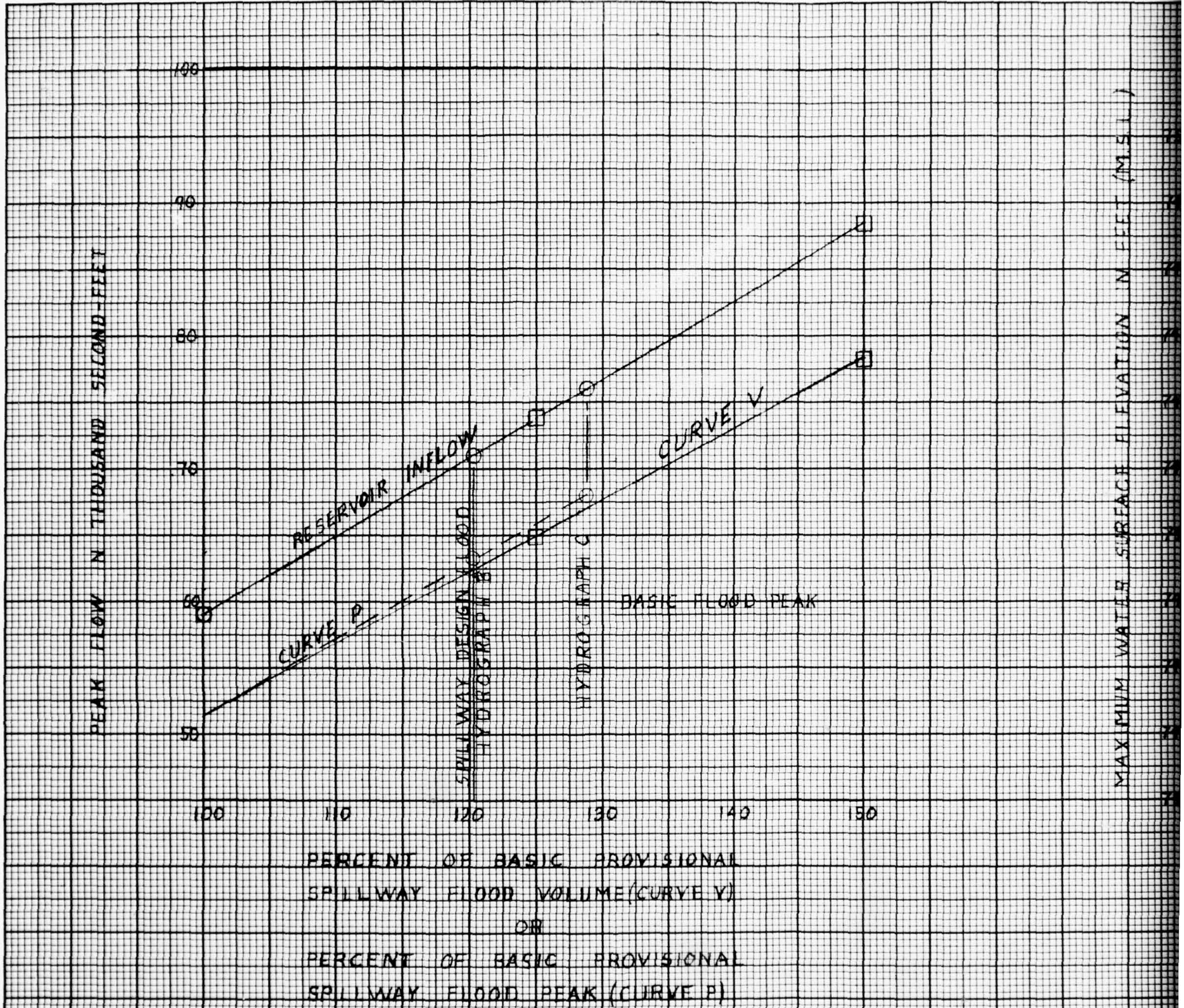


PLATE D-27

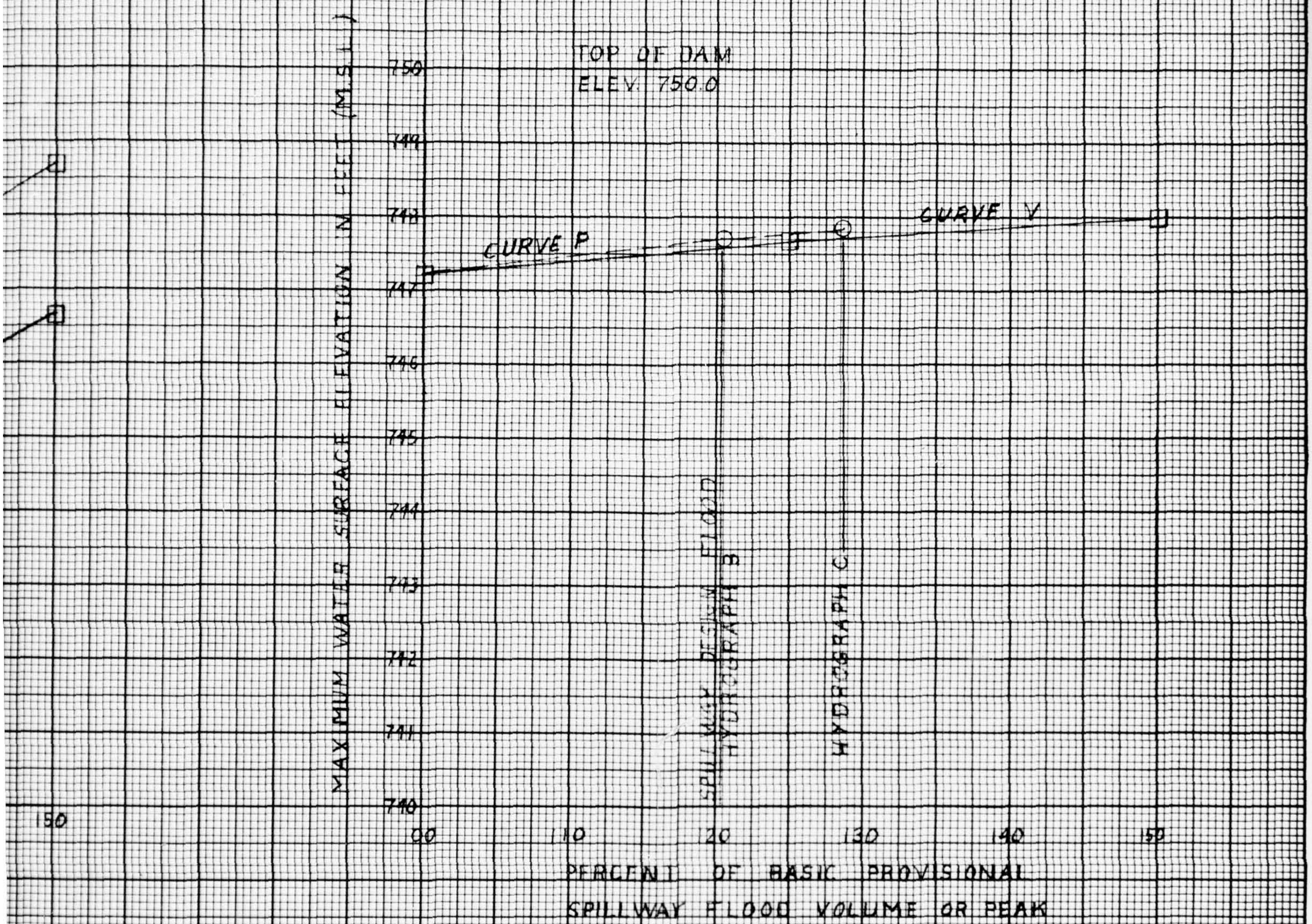
CORPS OF ENGINEERS



NOTE:

Curves V and P represent results of routings with initial pool elevation 745.0 a limiting induced surcharge pool elevation of 748.0. If maximum induced surcharge is reached, the gates are opened at a rate that will prevent further surcharging of When the peak outflow is reached the gate setting remains constant until reservoir pool re elevation 745.0 Letter V of curve indicates volume of basic flood increased by vary the unit hydrograph remaining constant, letter P indicates volume of basic flood and flood peak increased by varying the unit hydrograph of basin above hea

U.S. ARMY



h initial pool elevation 745.0 (top of gates) and
ximum induced surcharge pool elevation is
vent further surcharging of the reservoir pool.
stant until reservoir pool returns to flood control
ic flood increased by various percentages.
tes volume of basic flood was constant
aph of basin above head of reservoir.

WABASH RIVER BASIN
CLIFTY CREEK RESERVOIR
CLIFTY CREEK, INDIANA

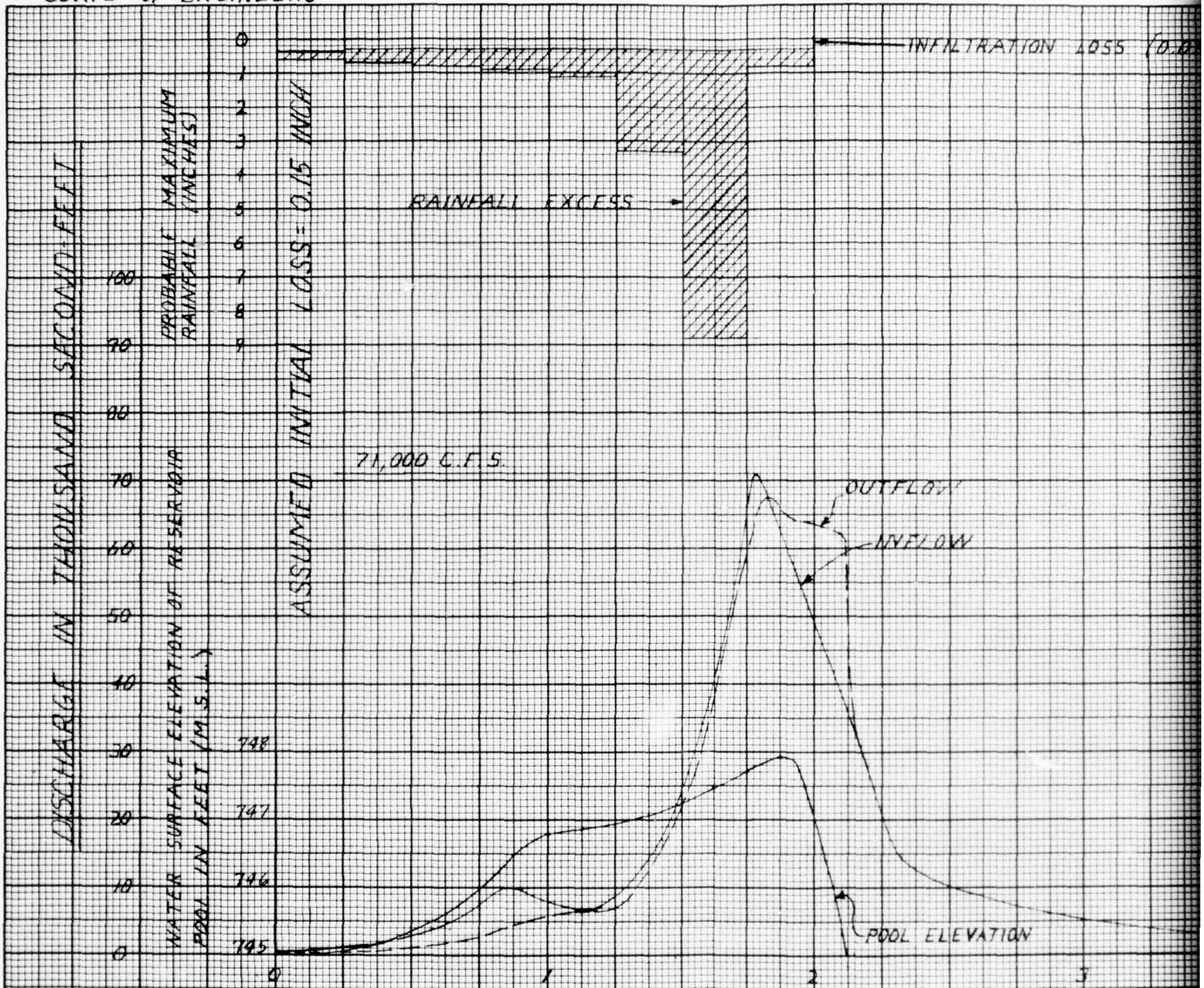
PERCENT OF BASIC
PROVISIONAL SPILLWAY FLOOD
PEAK-RESERVOIR ELEVATION
INFLOW-OUTFLOW CURVES

ORLED-H

LOUISVILLE, KY NOV 1963

PLATE D-28

CORPS OF ENGINEERS



NOTE:

Drainage area - 139.8 square miles

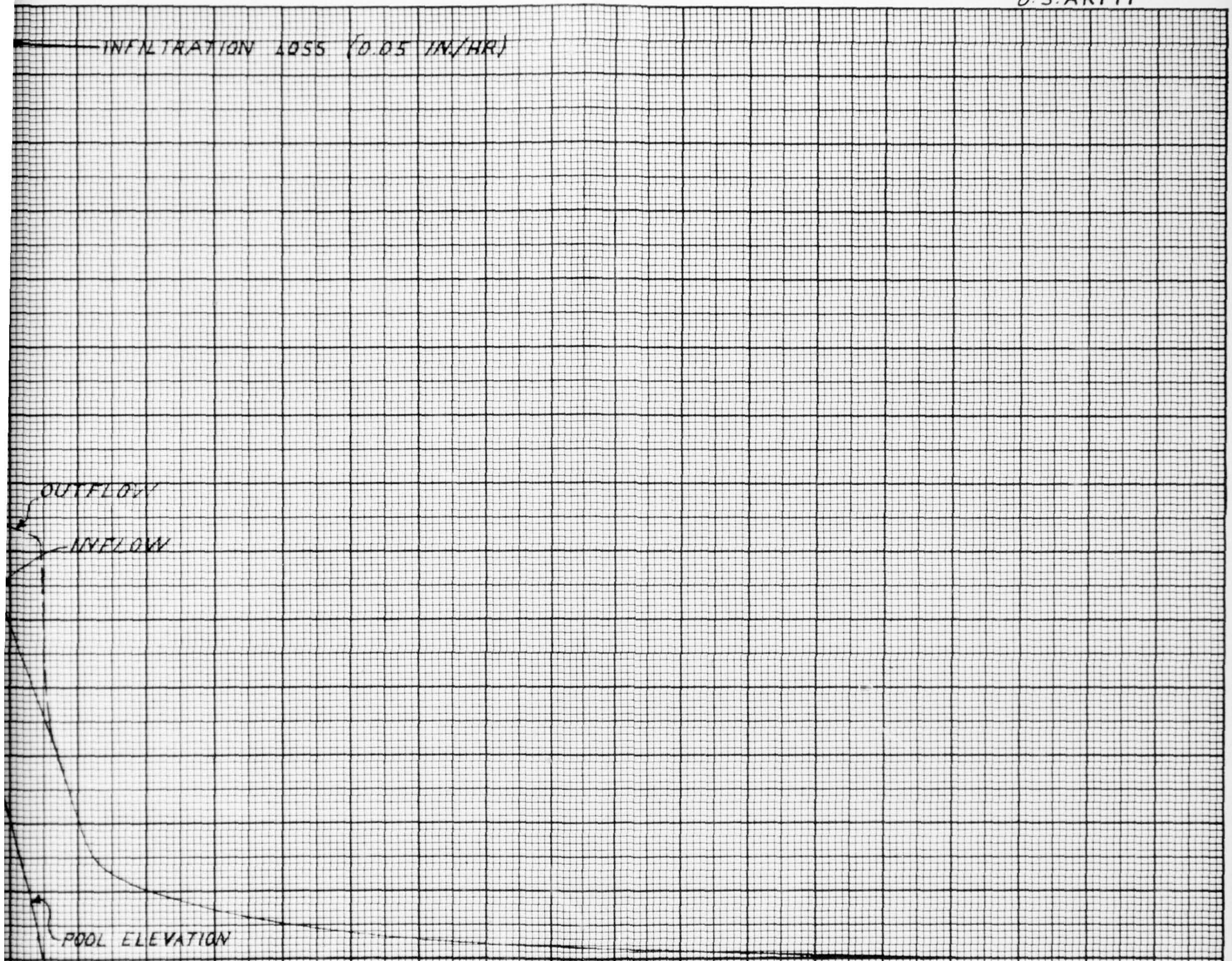
Spillway design flood is routed through the reservoir as explained in not

Two sluices are of rectangular section, each 4-foot wide by 6-foot h

an ogee channel type of 140-foot width and crest at elevation

foot piers divide the overflow section into three 40-foot openings

U.S. ARMY



NG OF RAINFALL-EXCESS

reservoir as explained in note on plate D-28.
ch 1-foot wide by 6-foot high. Spillway is
and crest at elevation 717.0. Two 10
into three 40-foot openings.

WABASH RIVER BASIN
CLIFTY CREEK RESERVOIR
CLIFTY CREEK, INDIANA

INFLOW - OUTFLOW -
STAGE HYDROGRAPHS FOR
SPILLWAY DESIGN FLOOD

ORLED-H

LOUISVILLE, KY REVISED FEB., 19[illegible]

PLATE D-29

CORPS OF ENGINEERS U.S. ARMY

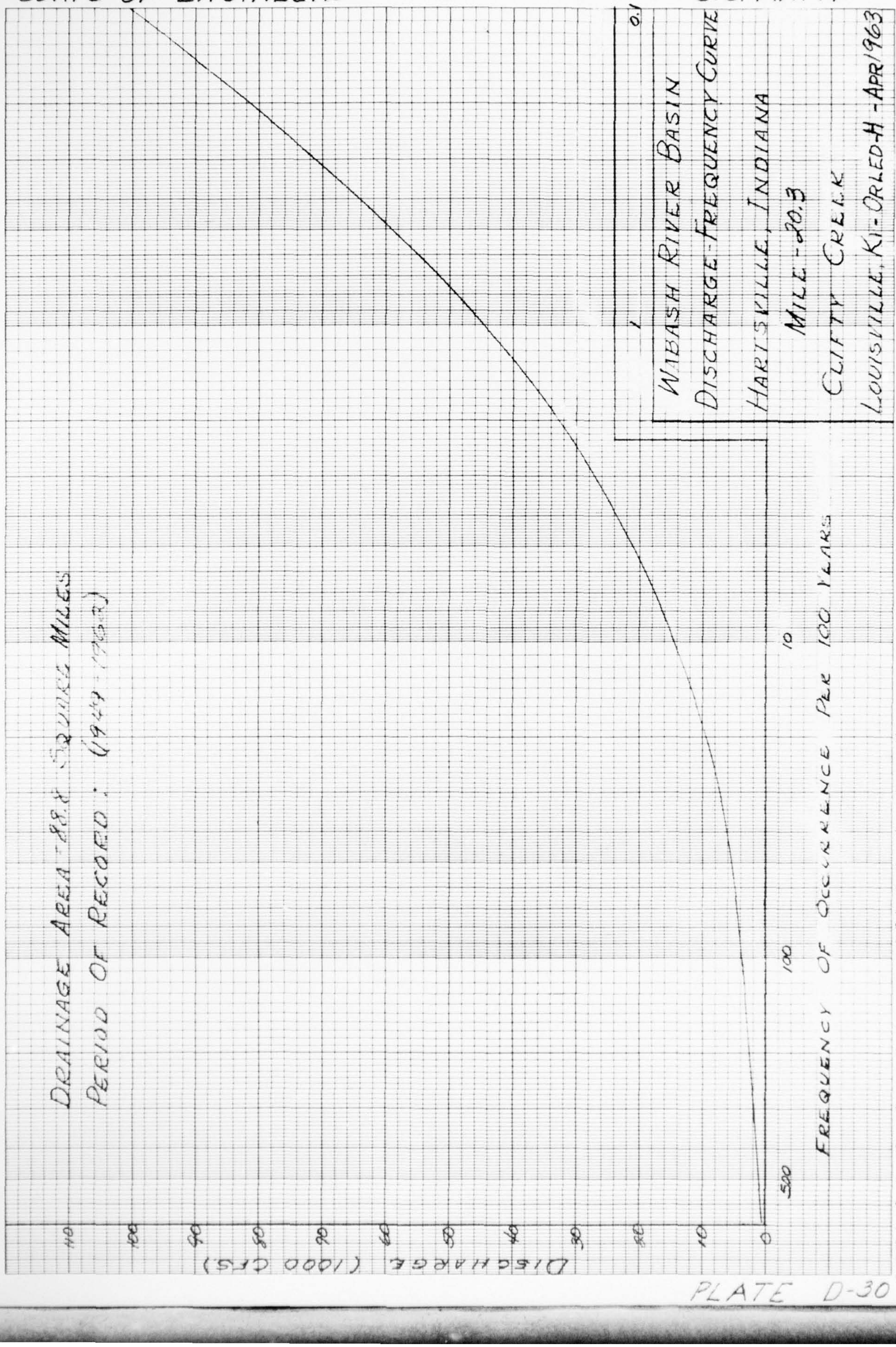


PLATE D-30

CORPS OF ENGINEERS U.S. ARMY

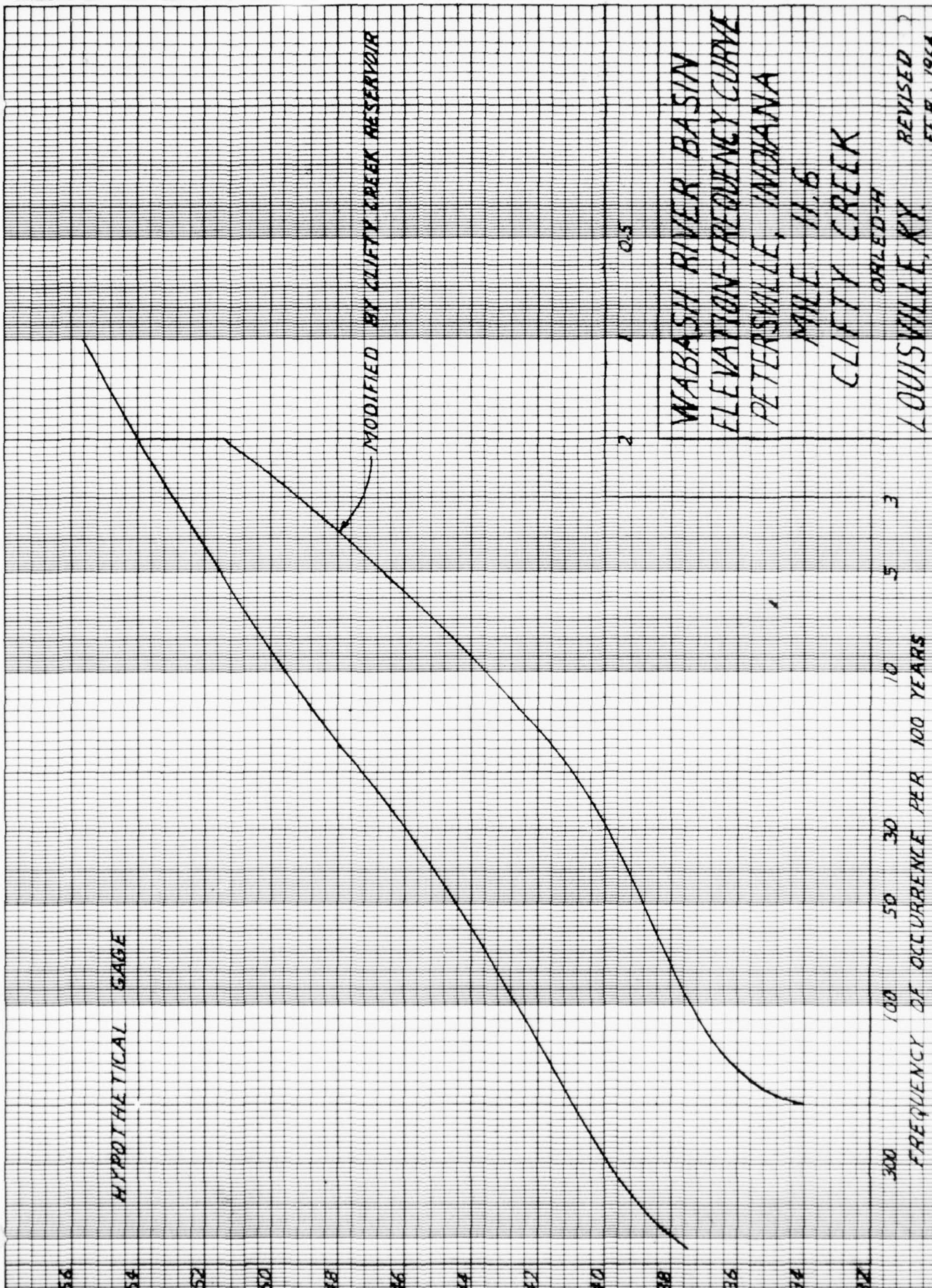


PLATE D-31

CORPS OF ENGINEERS U.S. ARMY

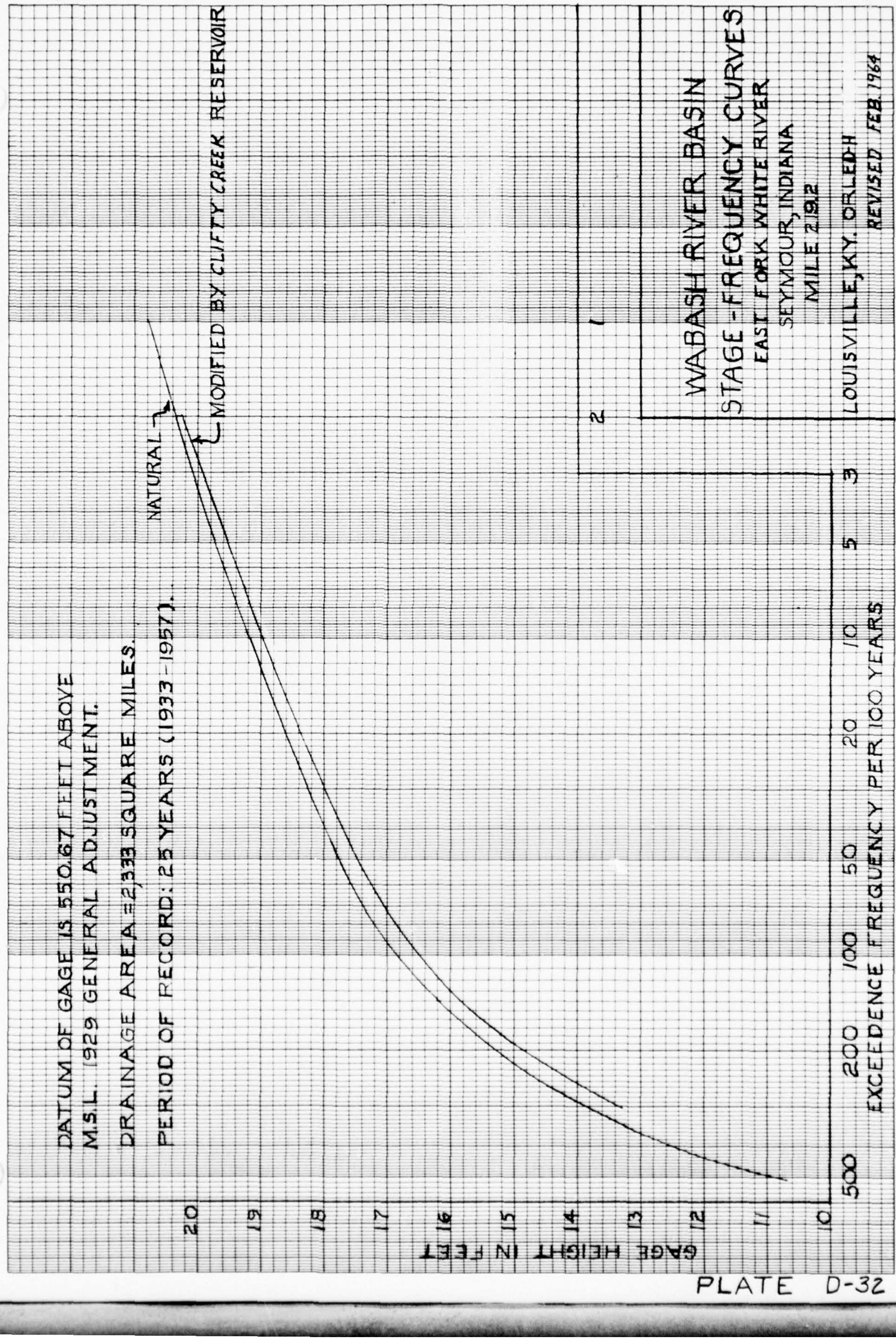
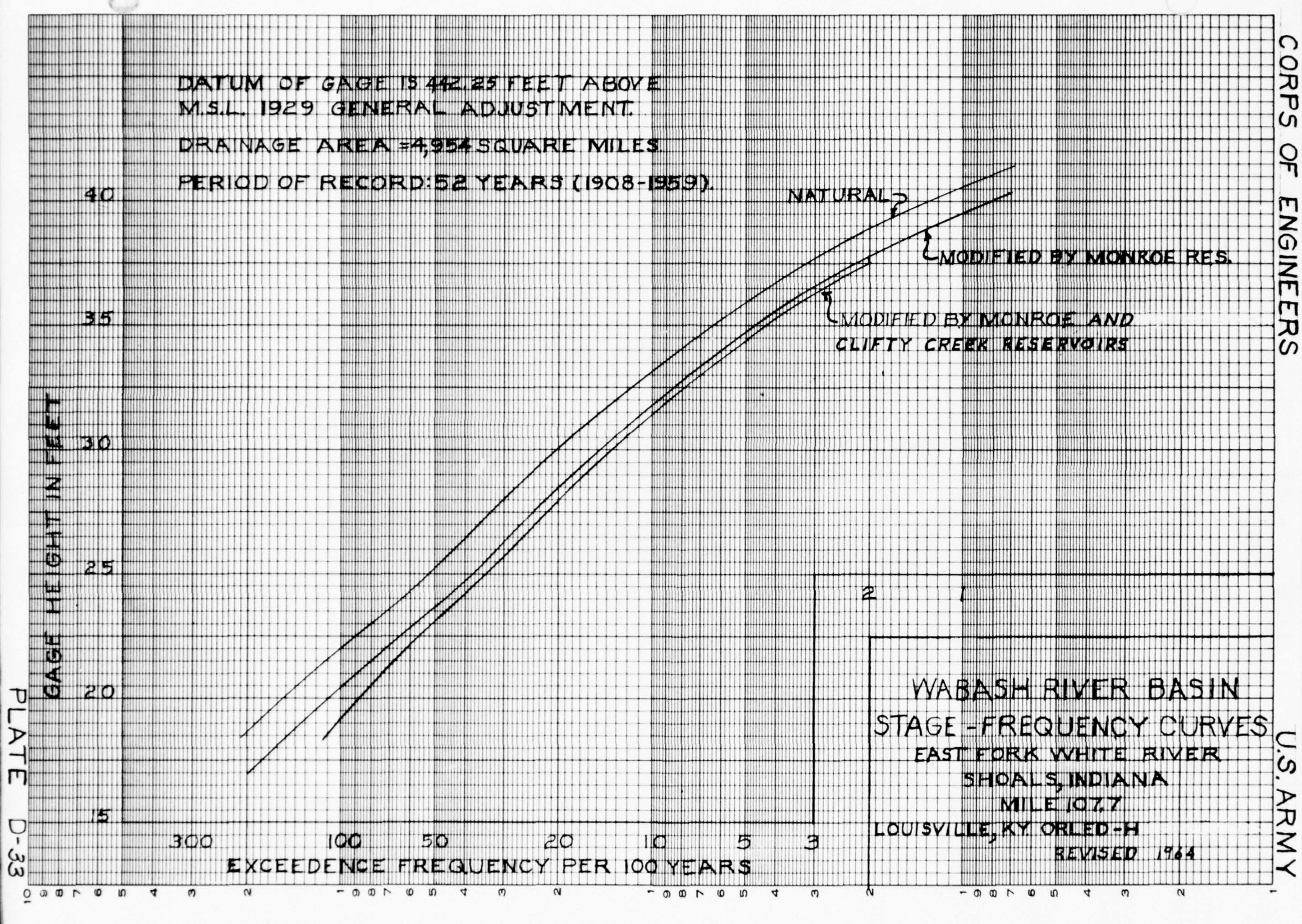
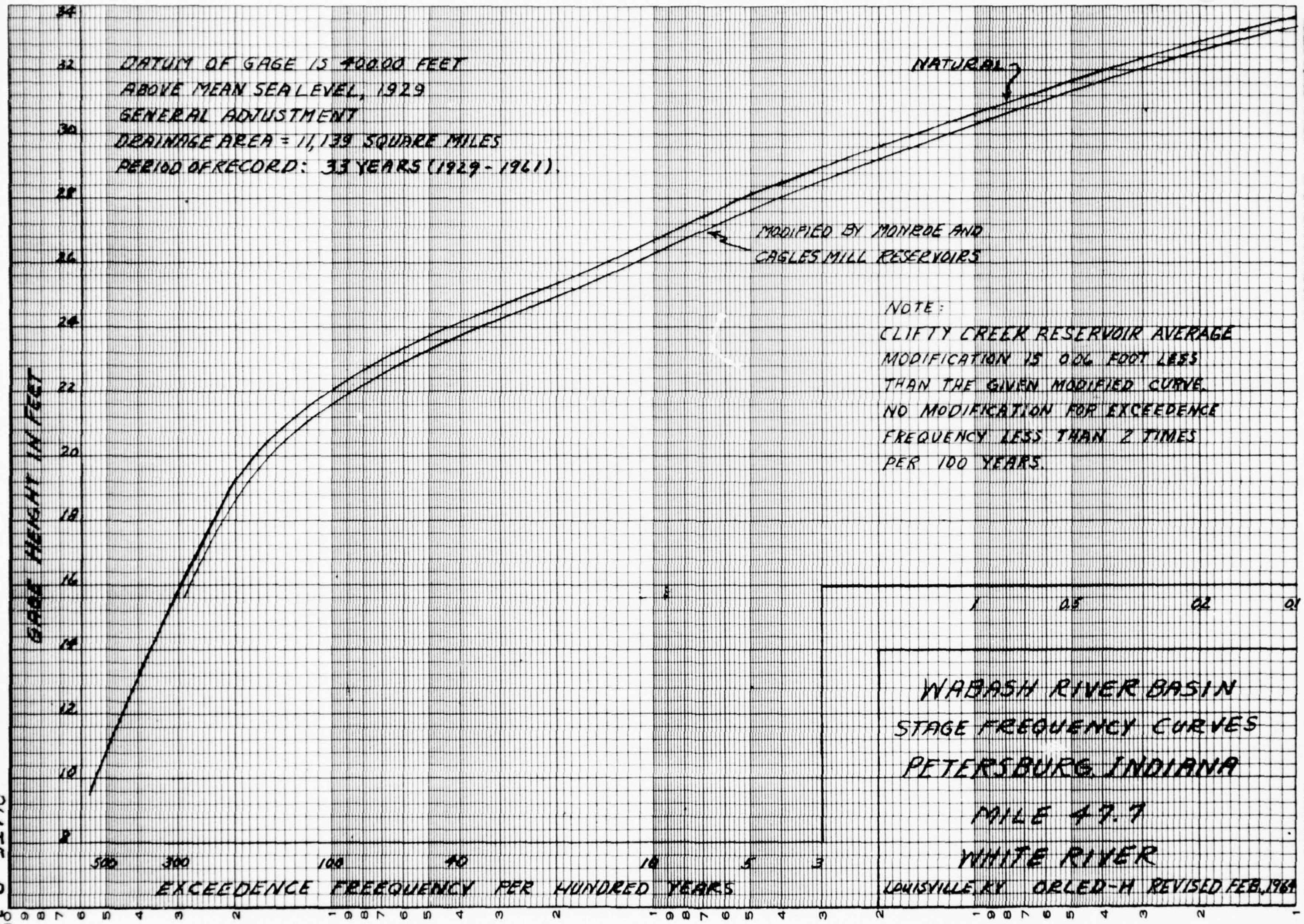
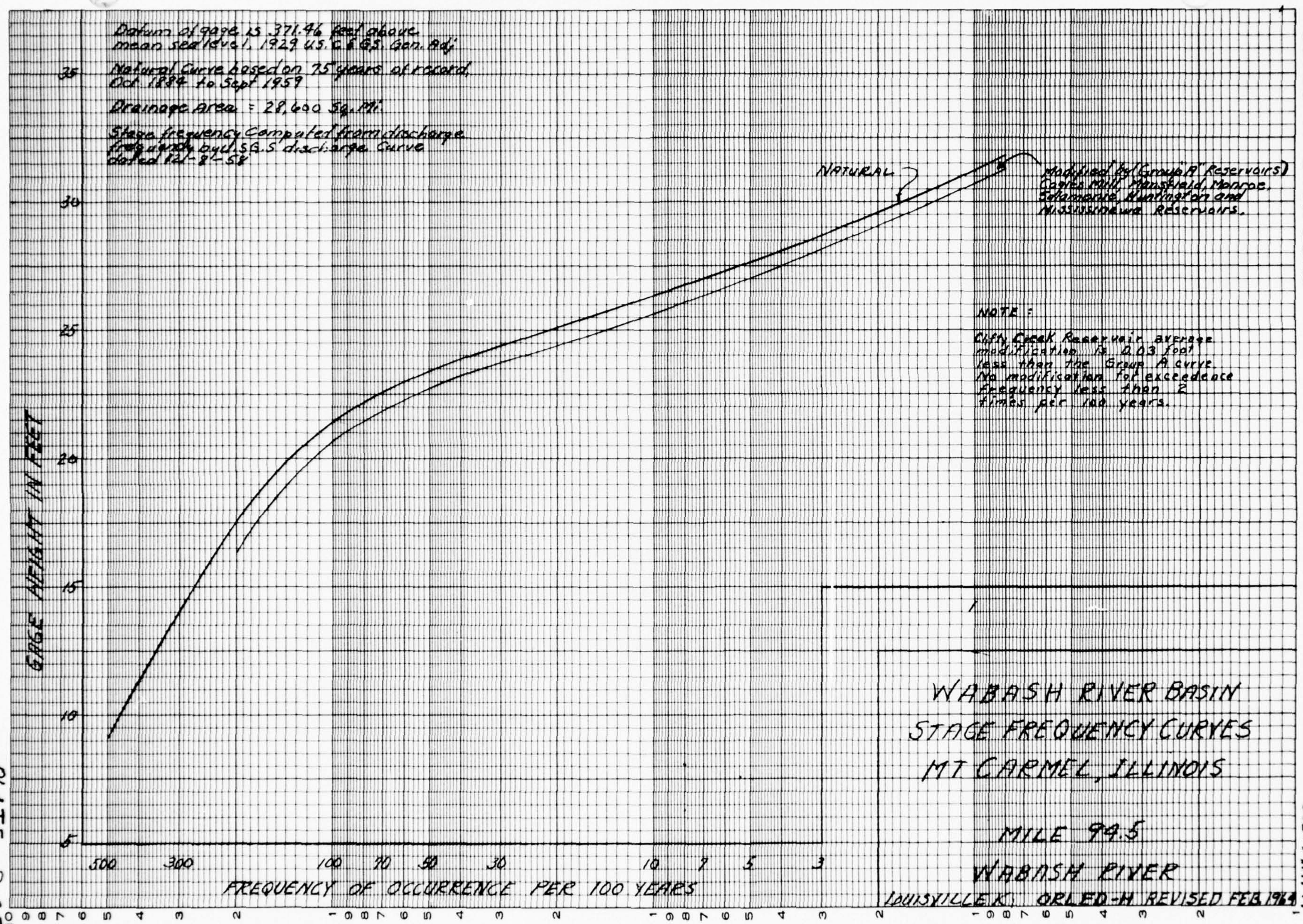
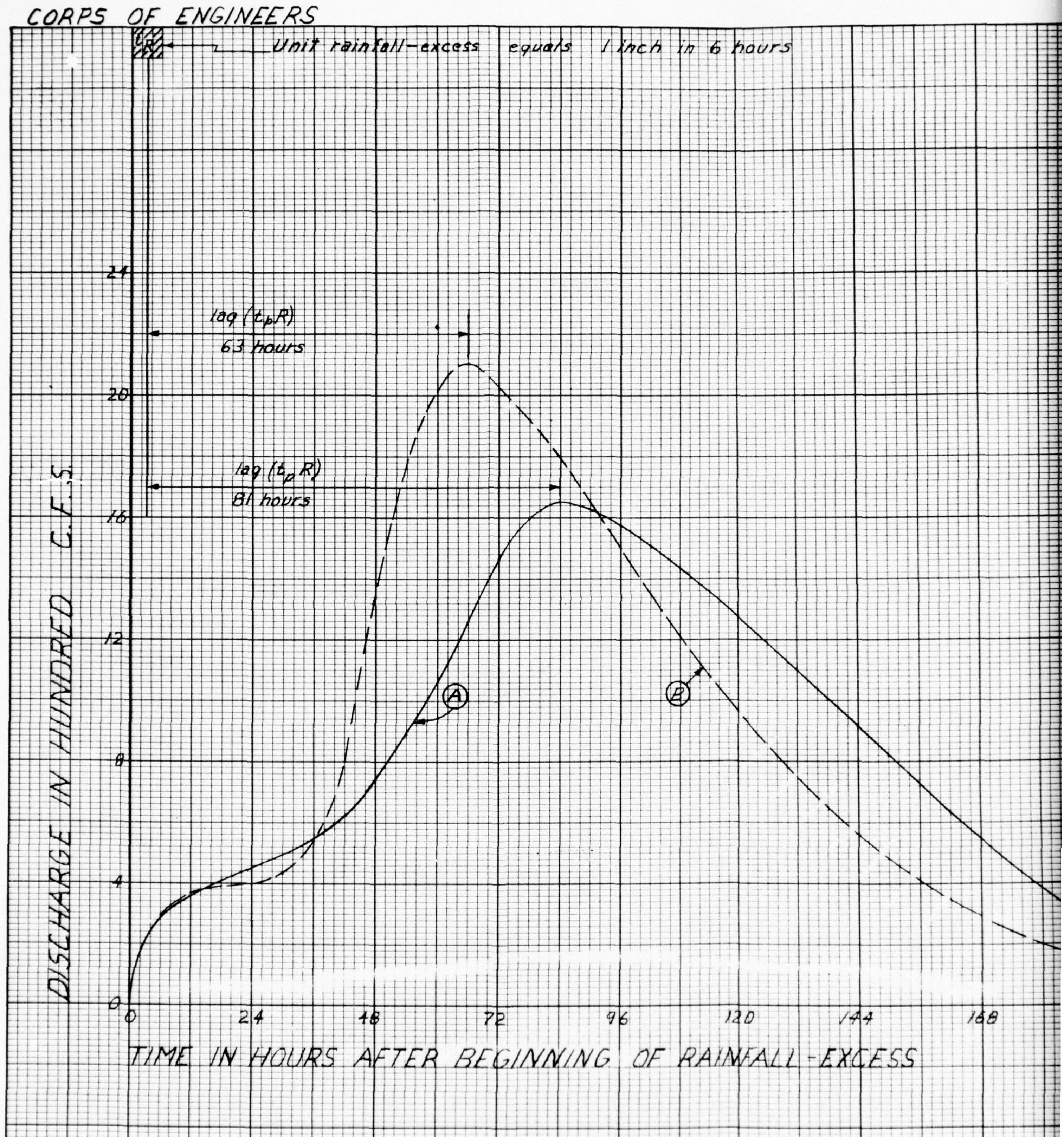


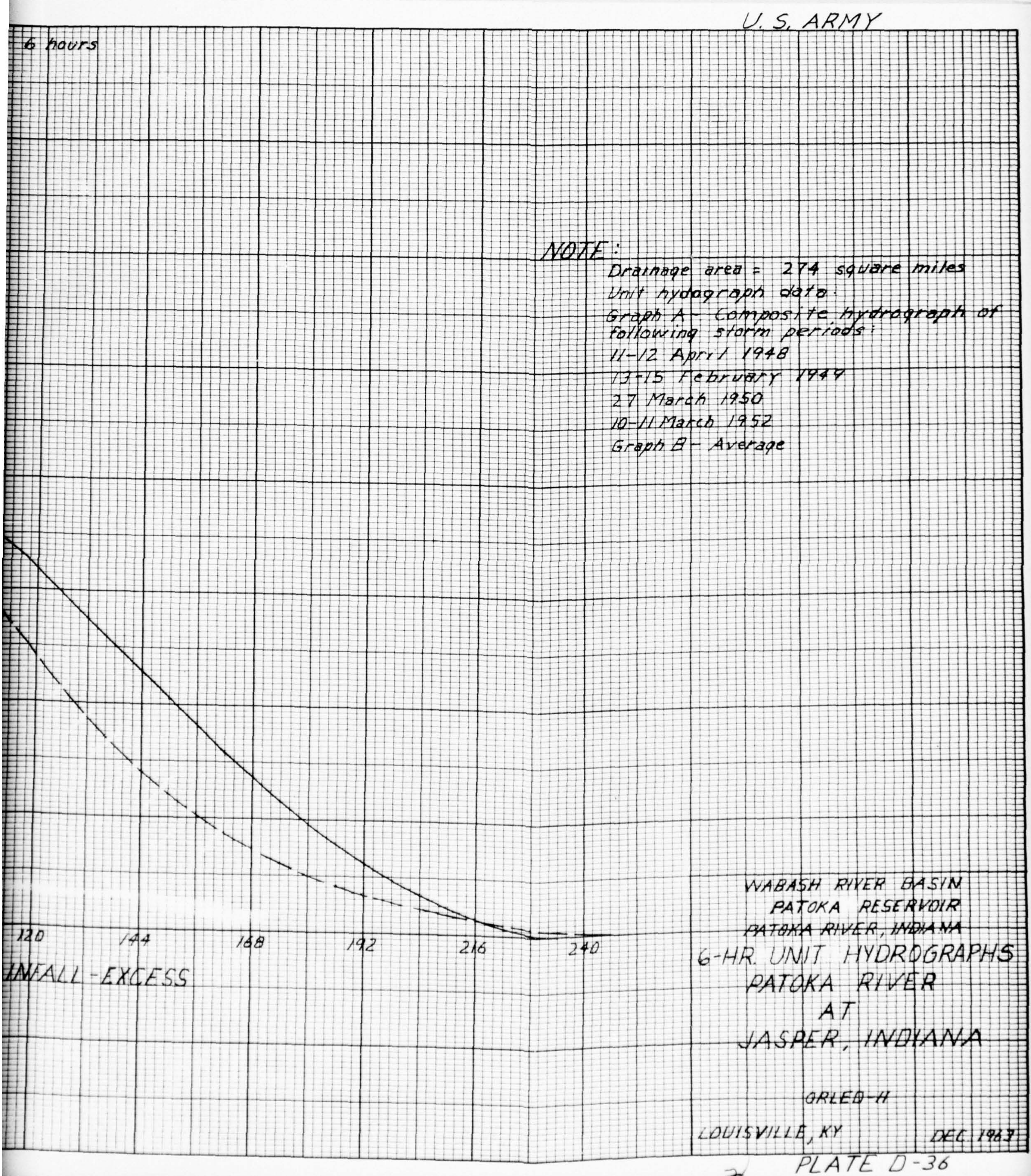
PLATE D-32

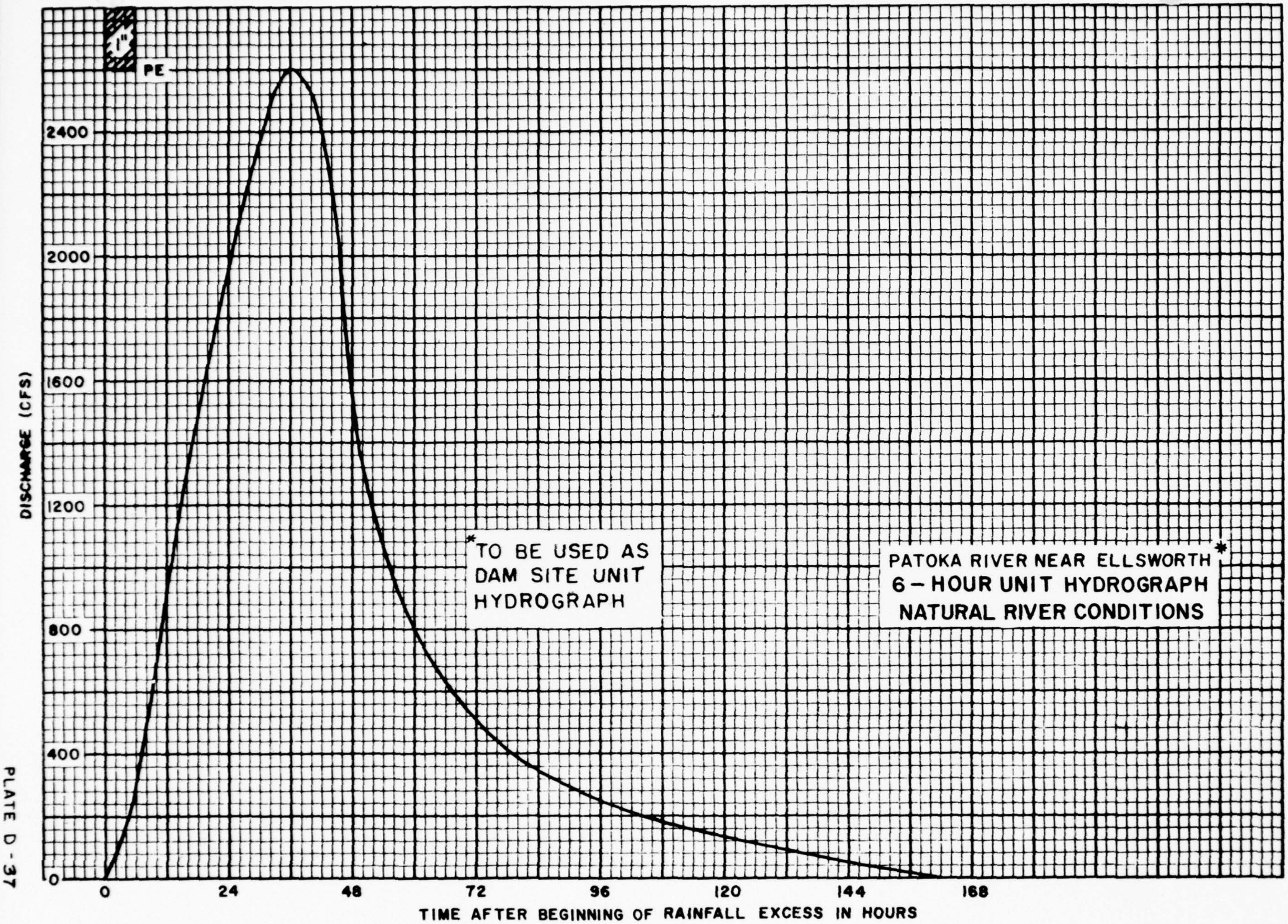

CORPS OF ENGINEERS
U.S. ARMY
DATUM OF GAGE IS 442.25 FEET ABOVE
M.S.L. 1929 GENERAL ADJUSTMENT.
DRAINAGE AREA = 4,954 SQUARE MILES.
PERIOD OF RECORD: 52 YEARS (1908-1959).
NATURAL
MODIFIED BY MONROE RES.
MODIFIED BY MONROE AND
CLIFTY CREEK RESERVOIRS
GAGE HEIGHT IN FEET
40
35
30
25
20
15
300
100
50
20
10
5
3
2
1
EXCEEDENCE FREQUENCY PER 100 YEARS
WABASH RIVER BASIN
STAGE - FREQUENCY CURVES
EAST FORK WHITE RIVER
SHOALS, INDIANA
MILE 107.7
LOUISVILLE, KY. ORLED-H
REVISED 1964
PLATE D-33

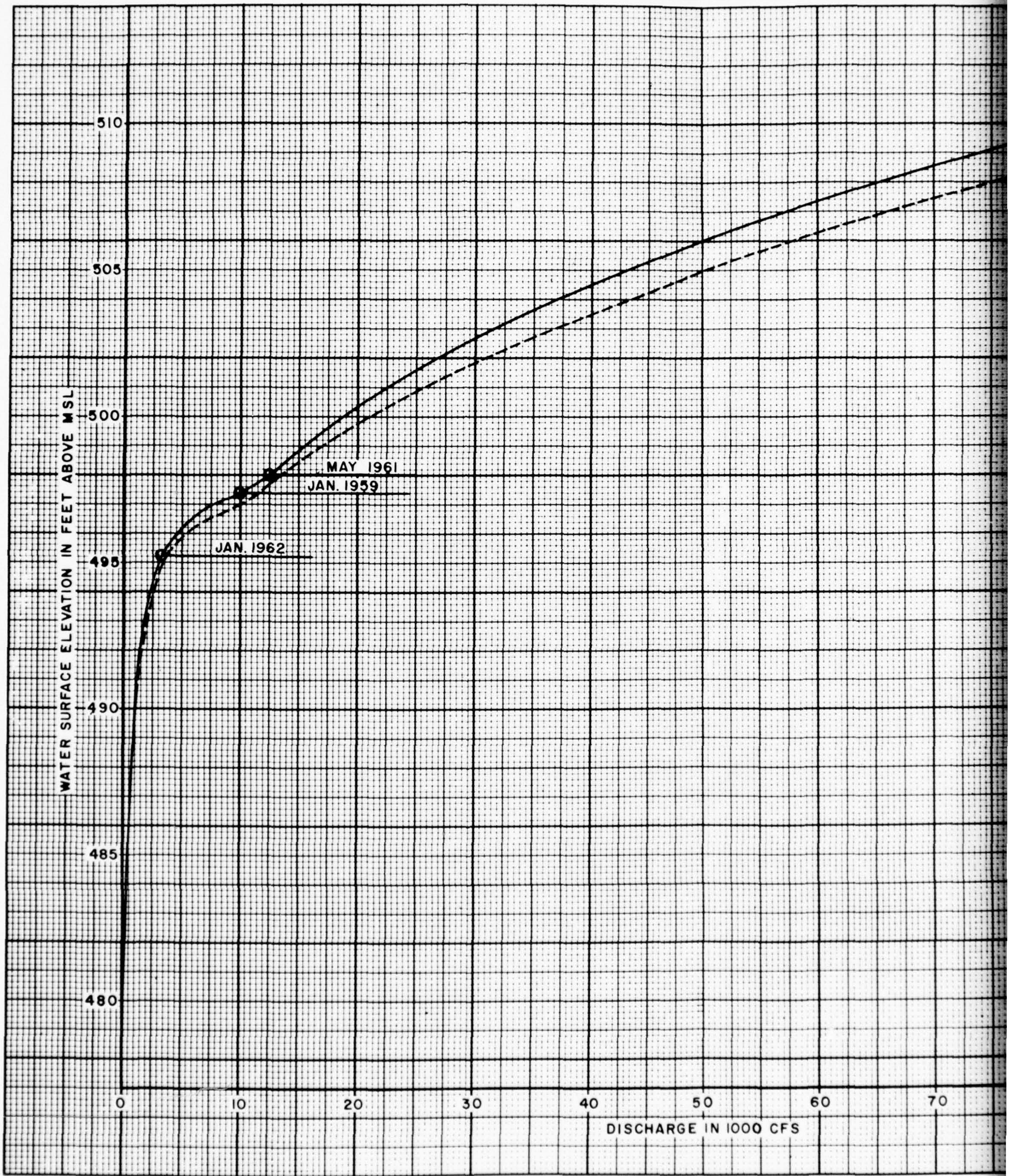

CORPS OF ENGINEERS
U.S. ARMY
DATUM OF GAGE IS 400.00 FEET
ABOVE MEAN SEA LEVEL, 1929
GENERAL ADJUSTMENT
DRAINAGE AREA = 11,139 SQUARE MILES
PERIOD OF RECORD: 33 YEARS (1929 - 1961).
NATURAL
MODIFIED BY MONROE AND
CAGLES MILL RESERVOIRS
NOTE:
CLIFTY CREEK RESERVOIR AVERAGE
MODIFICATION IS 0.06 FOOT LESS
THAN THE GIVEN MODIFIED CURVE.
NO MODIFICATION FOR EXCEEDENCE
FREQUENCY LESS THAN 2 TIMES
PER 100 YEARS.
GAGE HEIGHT IN FEET
34
32
30
28
26
24
22
20
18
16
14
12
10
8
500
300
100
40
10
5
3
1
0.5
0.2
0.1
EXCEEDENCE FREEQUENCY PER HUNDRED YEARS
WABASH RIVER BASIN
STAGE FREQUENCY CURVES
PETERSBURG INDIANA
MILE 47.7
WHITE RIVER
LOUISVILLE KY. ORLED-H REVISED FEB. 1964


Datum of gage is 371.46 feet above mean sea level, 1929 U.S.C.&G.S. Gen. Adj.
Natural Curve based on 75 years of record, Oct 1884 to Sept 1959
Drainage area = 28,600 Sq. Mi.
Stage frequency computed from discharge frequency and S.G.S discharge curve dated 12-8-58
NATURAL
Modified by (Group "A" Reservoirs) Cagles Mill, Mansfield, Monroe, Salamonie, Huntington and Mississinewa Reservoirs.
NOTE:
Clifty Creek Reservoir average modification is 0.03 foot less than the Group A curve. No modification for exceedence frequency less than 2 times per 100 years.
GAGE HEIGHT IN FEET
35
30
25
20
15
10
5
500
300
100
70
50
30
10
7
5
3
FREQUENCY OF OCCURRENCE PER 100 YEARS
WABASH RIVER BASIN
STAGE FREQUENCY CURVES
MT CARMEL, ILLINOIS
MILE 94.5
WABASH RIVER
LOUISVILLE K. ORLED-H REVISED FEB 1964

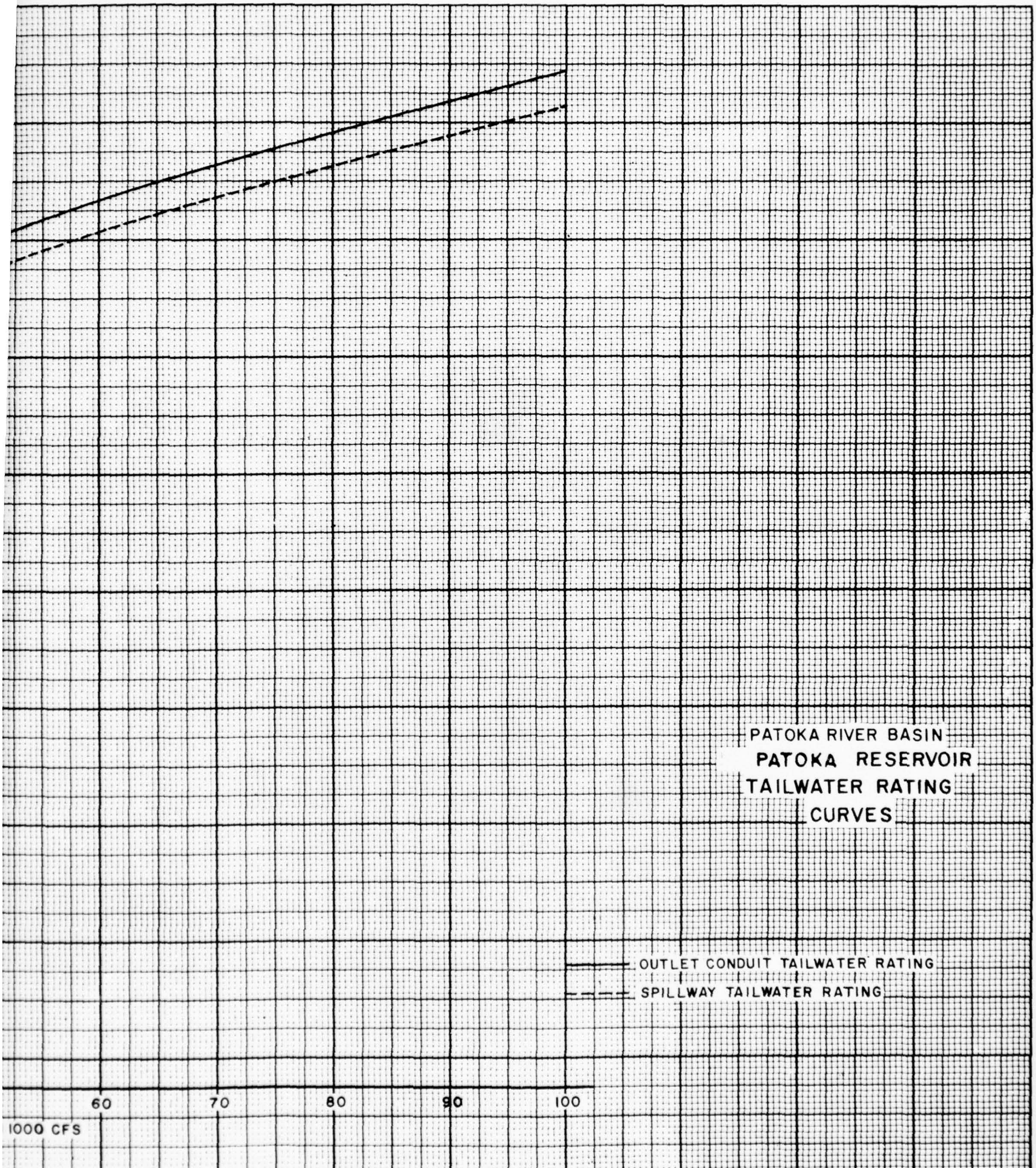

CORPS OF ENGINEERS
tR
Unit rainfall-excess equals 1 inch in 6 hours
lag (t_pR)
63 hours
lag (t_pR)
81 hours
A
B
DISCHARGE IN HUNDRED C.F.S.
0
4
8
12
16
20
24
0
24
48
72
96
120
144
168
TIME IN HOURS AFTER BEGINNING OF RAINFALL-EXCESS


U. S. ARMY
6 hours
NOTE:
Drainage area = 274 square miles
Unit hydograph data:
Graph A - Composite hydrograph of following storm periods:
11-12 April 1948
13-15 February 1949
27 March 1950
10-11 March 1952
Graph B - Average
120
144
168
192
216
240
INFALL-EXCESS
WABASH RIVER BASIN
PATOKA RESERVOIR
PATOKA RIVER, INDIANA
6-HR. UNIT HYDROGRAPHS
PATOKA RIVER
AT
JASPER, INDIANA
ORLED-H
LOUISVILLE, KY
DEC 1967
PLATE D-36

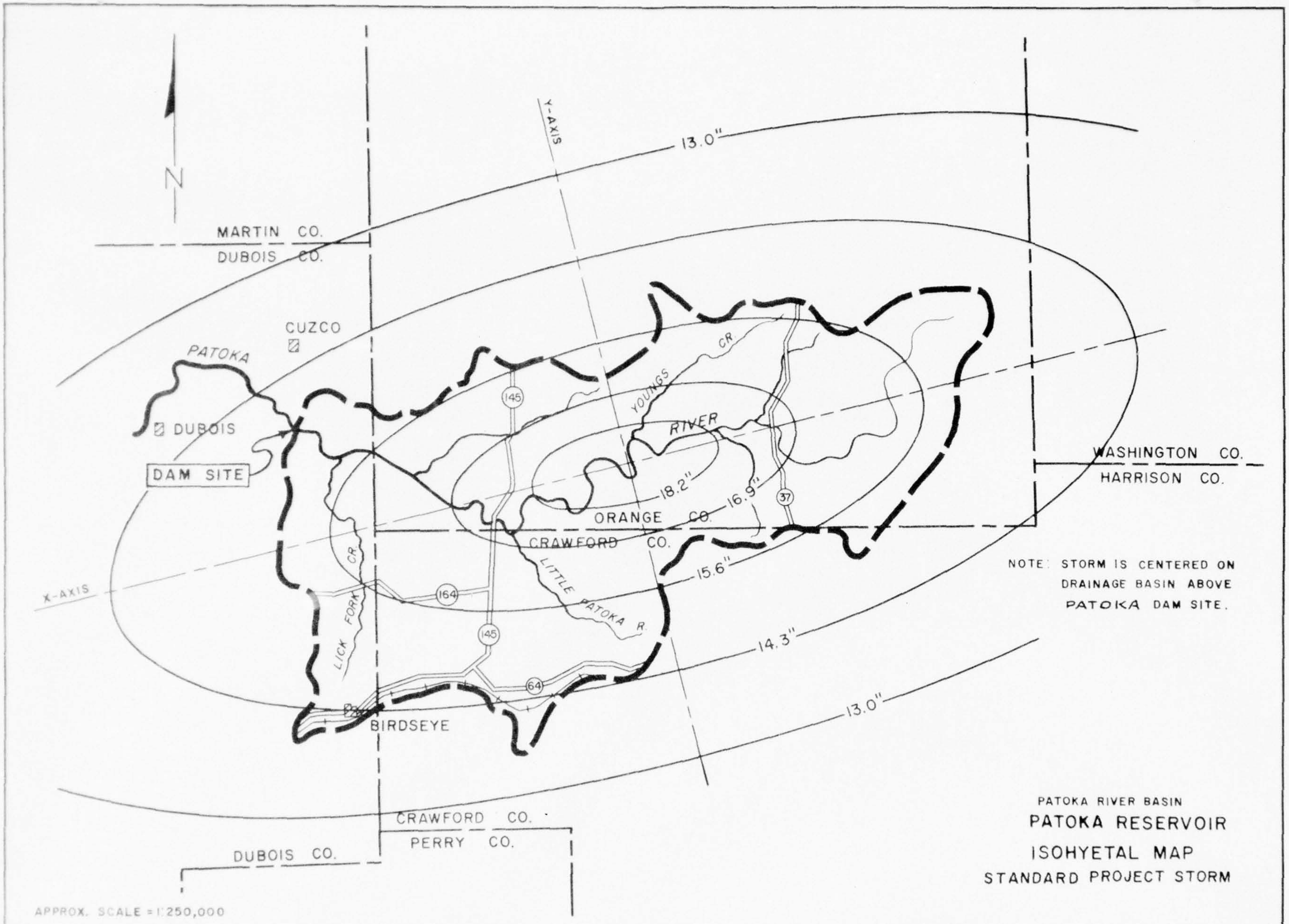

1"
PE
2400
2000
1600
1200
800
400
0
DISCHARGE (CFS)
0
24
48
72
96
120
144
168
TIME AFTER BEGINNING OF RAINFALL EXCESS IN HOURS
*TO BE USED AS
DAM SITE UNIT
HYDROGRAPH
PATOKA RIVER NEAR ELLSWORTH*
6 – HOUR UNIT HYDROGRAPH
NATURAL RIVER CONDITIONS


WATER SURFACE ELEVATION IN FEET ABOVE MSL
510
505
500
495
490
485
480
MAY 1961
JAN. 1959
JAN. 1962
0
10
20
30
40
50
60
70
DISCHARGE IN 1000 CFS

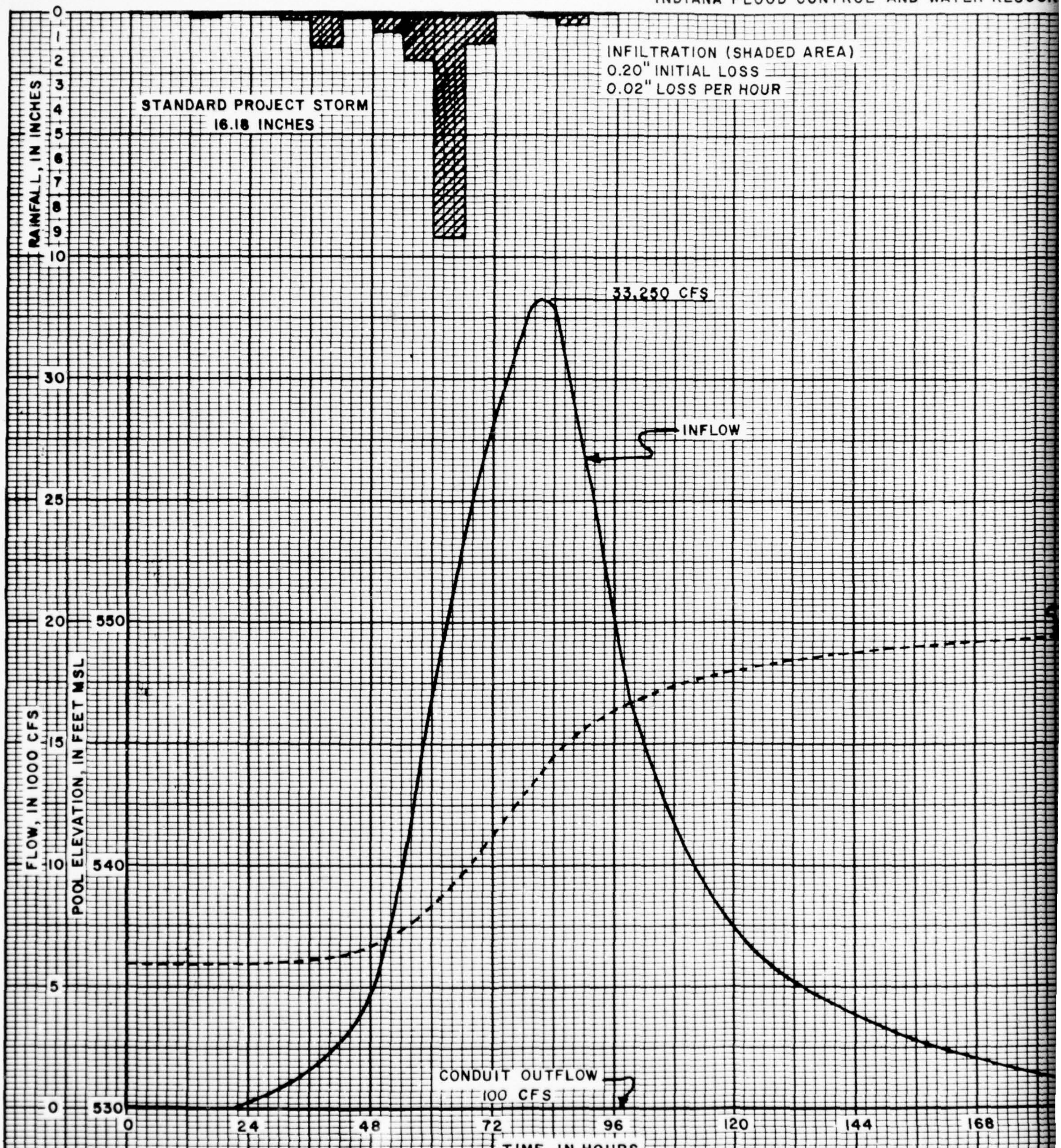
ODD CONTROL AND WATER RESOURCES COMMISSION

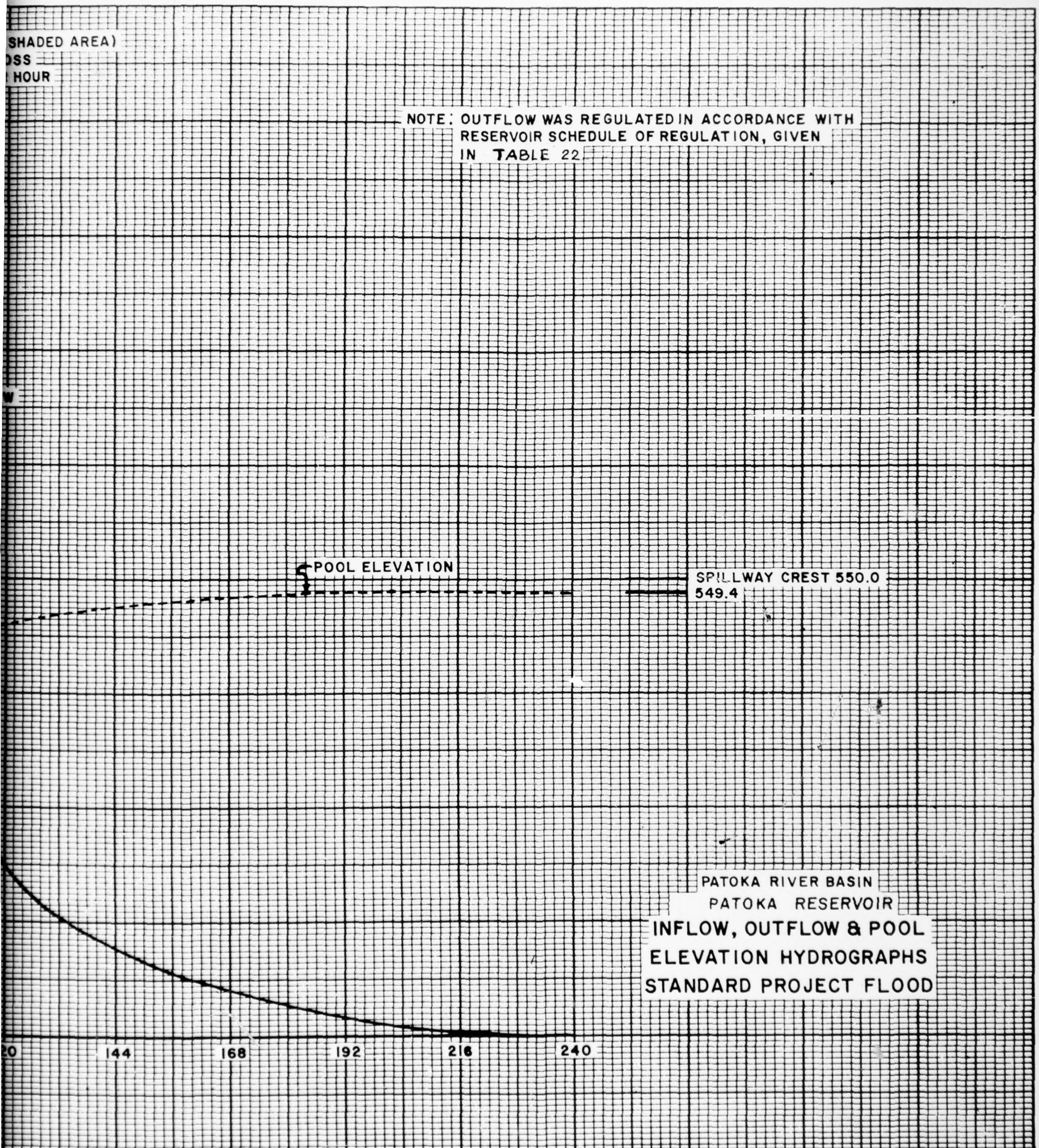


INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION

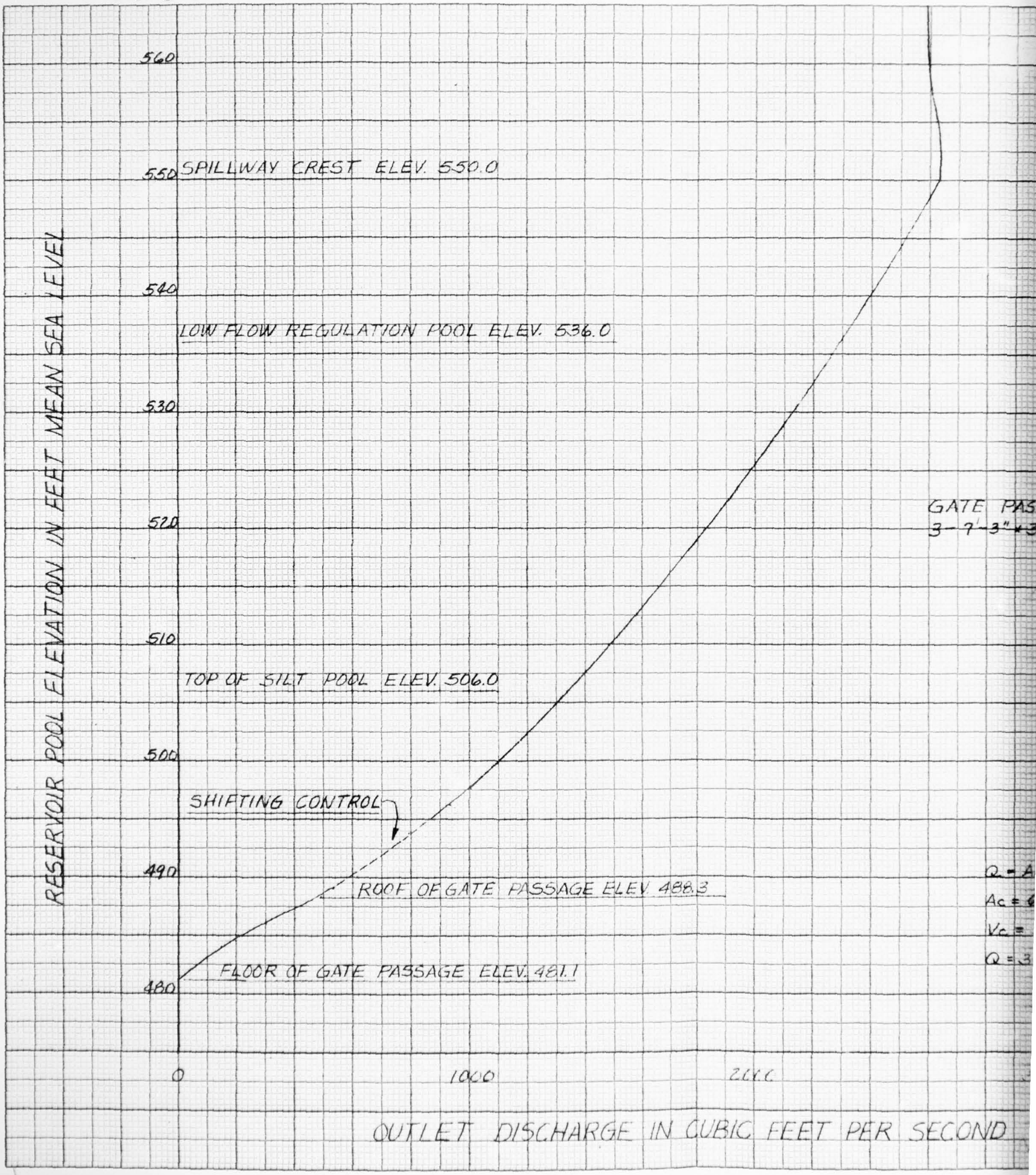


PATOKA RIVER BASIN
PATOKA RESERVOIR
ISOHYETAL MAP
STANDARD PROJECT STORM


INFILTRATION (SHADED AREA)
0.20" INITIAL LOSS
0.02" LOSS PER HOUR
STANDARD PROJECT STORM
16.18 INCHES
RAINFALL, IN INCHES
33,250 CFS
INFLOW
FLOW, IN 1000 CFS
POOL ELEVATION, IN FEET MSL
CONDUIT OUTFLOW
100 CFS
TIME, IN HOURS
0
24
48
72
96
120
144
168
530
540
550


SHADED AREA)
OSS
HOUR
NOTE: OUTFLOW WAS REGULATED IN ACCORDANCE WITH RESERVOIR SCHEDULE OF REGULATION, GIVEN IN TABLE 22
W
POOL ELEVATION
SPILLWAY CREST 550.0
549.4
PATOKA RIVER BASIN
PATOKA RESERVOIR
INFLOW, OUTFLOW & POOL ELEVATION HYDROGRAPHS
STANDARD PROJECT FLOOD
20
144
168
192
216
240

CORPS OF ENGINEERS



U.S. ARMY

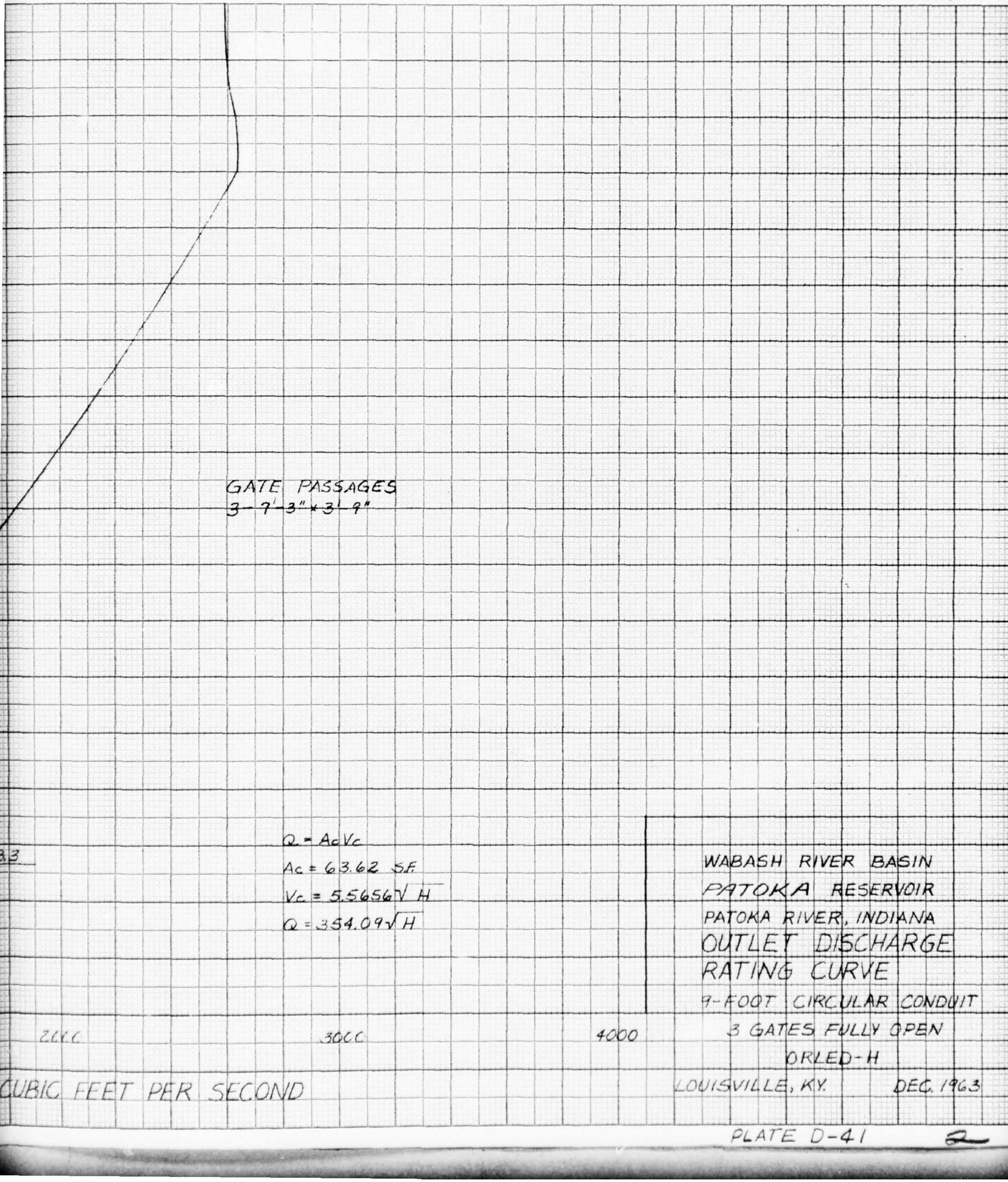
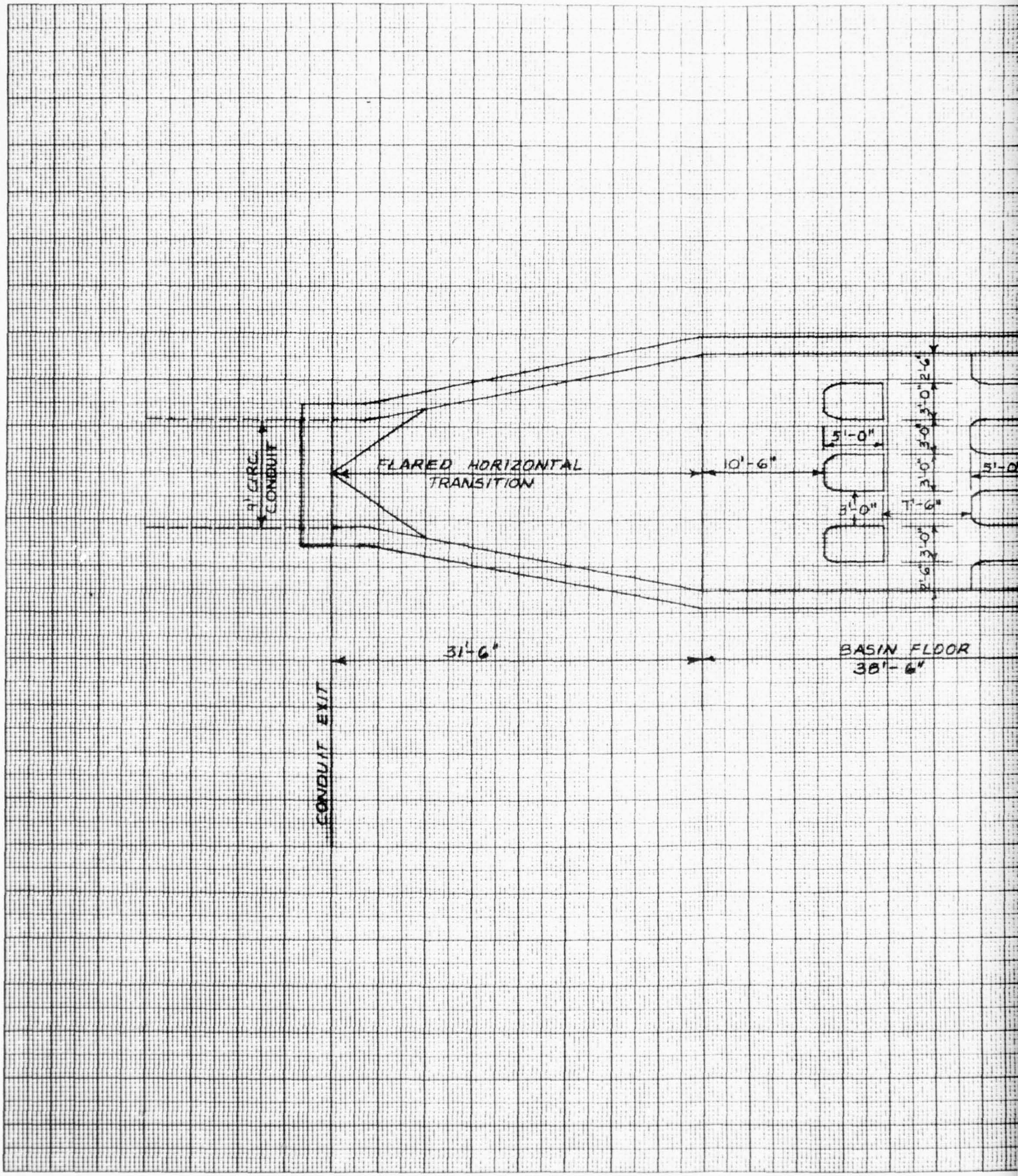
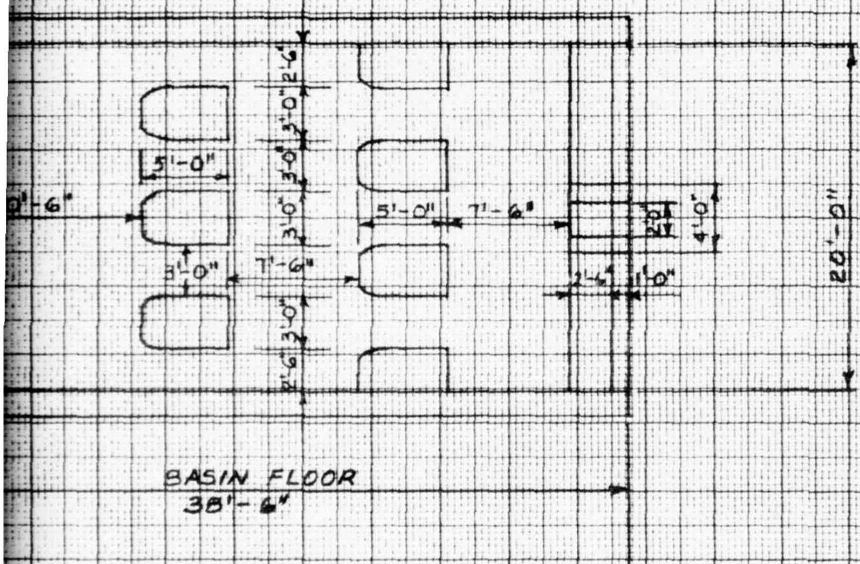


PLATE D-41

CORPS OF ENGINEERS



U.S. ARMY



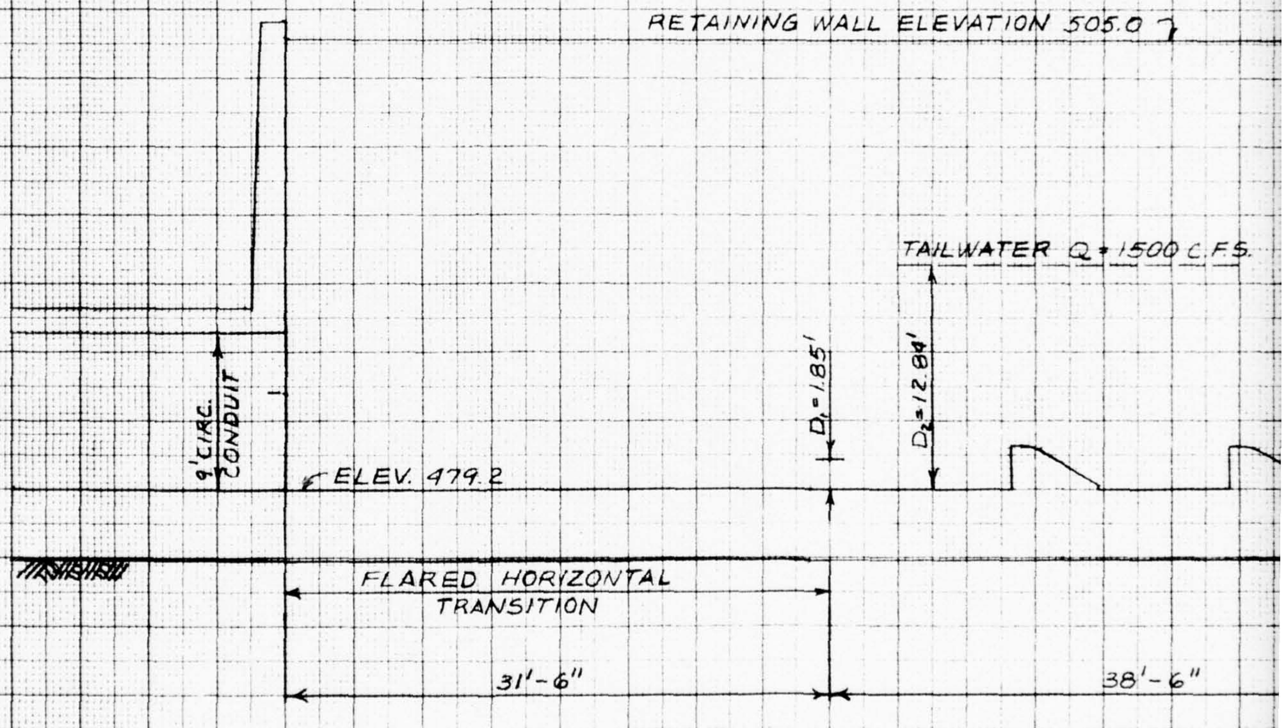
WABASH RIVER BASIN
PATOKA RESERVOIR
PATOKA RIVER, INDIANA

PLAN
OF
STILLING BASIN
SCALE: 1" = 10'
ORLED-H
LOUISVILLE, KY. DEC. 1963

PLATE D-42

2

CORPS OF ENGINEERS

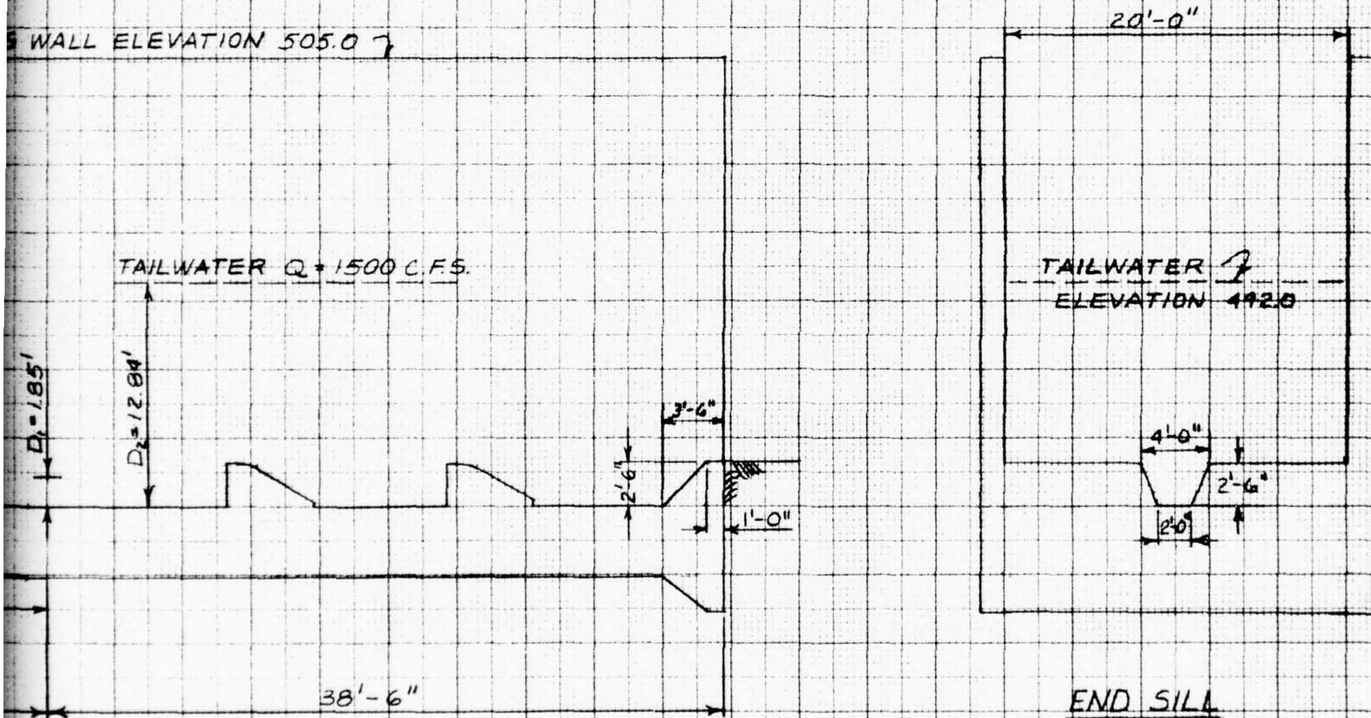


SECTION OF STILLING BASIN

NOTE:

The stilling basin is designed on a basis of pool elevation 550.0 t
release of 1500 c.f.s. which requires two gates to be open 3.4 feet
remaining gate closed. Width in transition range varies from
conduit exit to 20 feet at end of horizontally flared section,
remains constant throughout length of stilling basin.

U.S. ARMY



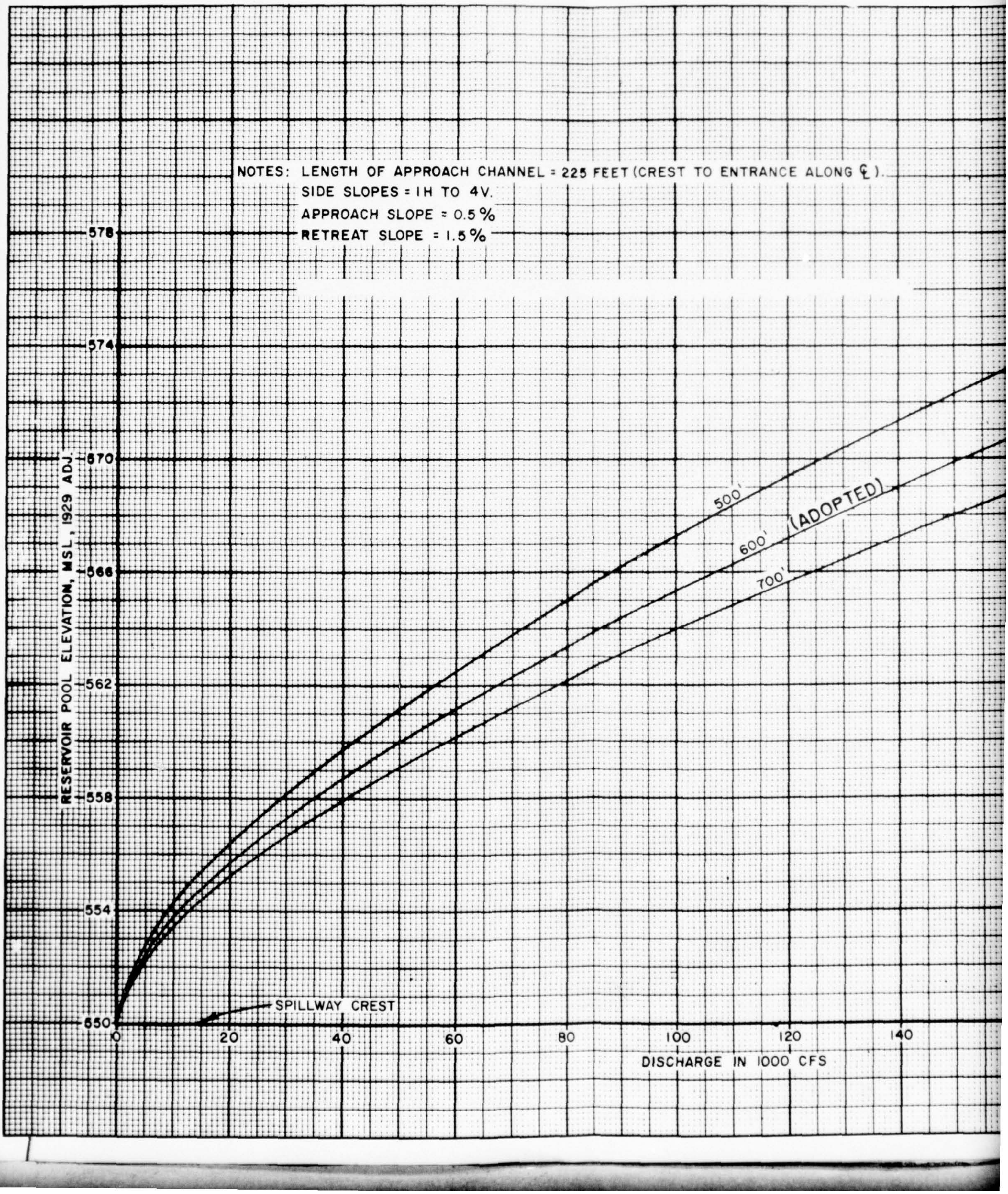
END SILL

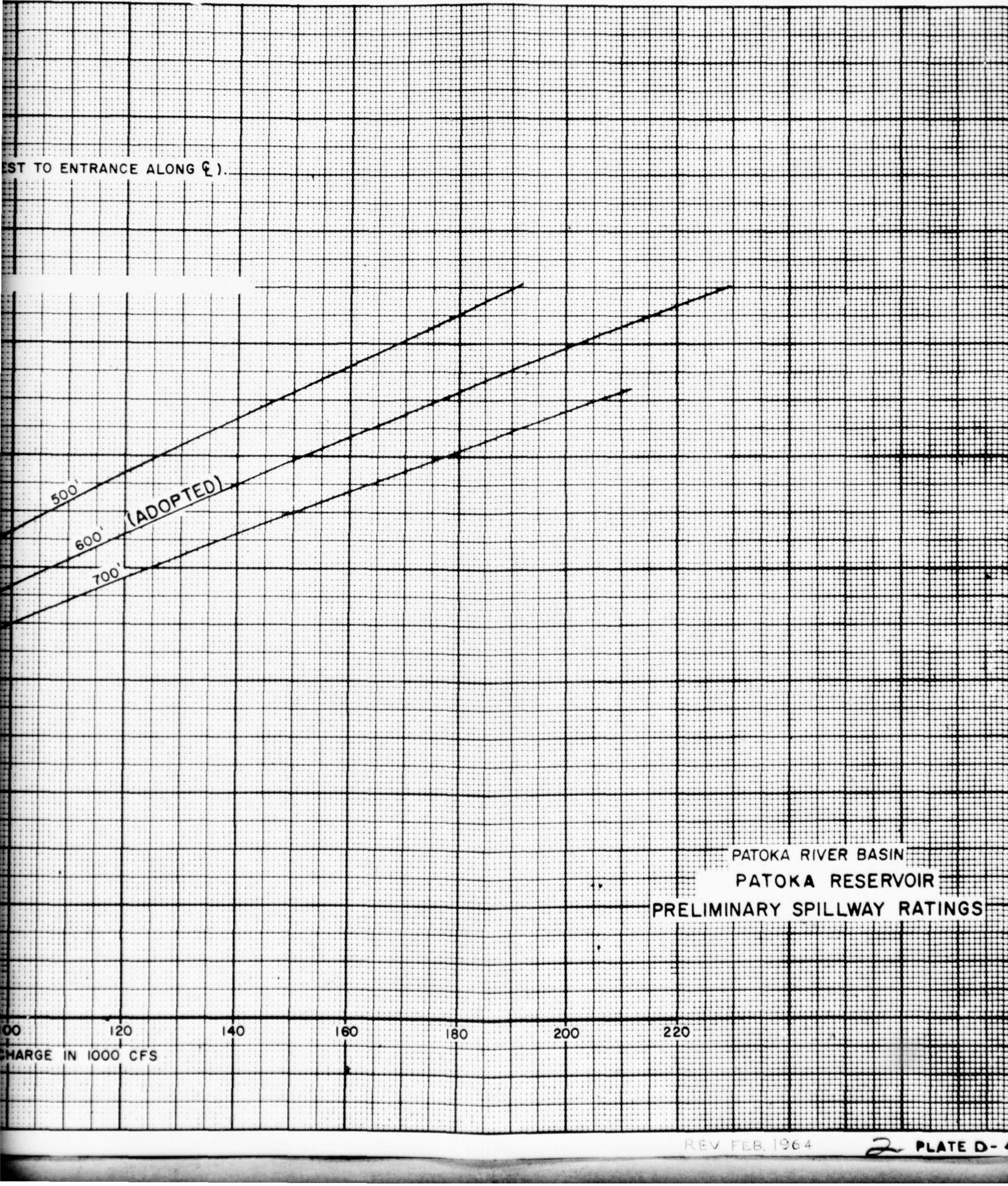
S BASIN

basis of pool elevation 550.0 for a
dres two gates to be open 3.4 feet and the
transition range varies from 9 feet at
of horizontally flared section, and
length of stilling basin.

WABASH RIVER BASIN
PATOKA RESERVOIR
PATOKA RIVER, INDIANA
HYDRAULIC ELEMENTS
OF
STILLING BASIN
SCALE: 1"=10'
ORLED-H
LOUISVILLE, KY. DEC. 1963

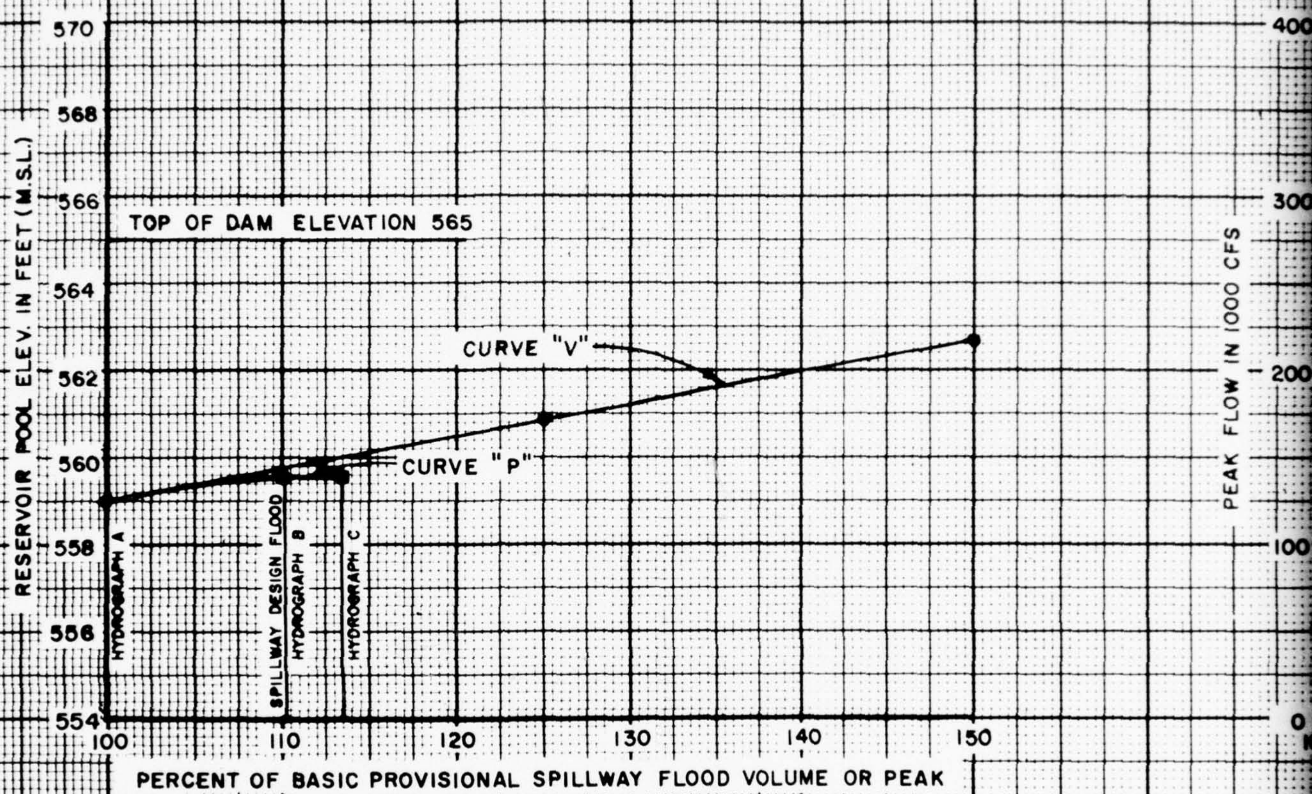
PLATE D-43


NOTES: LENGTH OF APPROACH CHANNEL = 225 FEET (CREST TO ENTRANCE ALONG ℄).
SIDE SLOPES = 1H TO 4V.
APPROACH SLOPE = 0.5%
RETREAT SLOPE = 1.5%
RESERVOIR POOL ELEVATION, MSL, 1929 ADJ.
578
574
570
566
562
558
554
550
500'
600' (ADOPTED)
700'
SPILLWAY CREST
0
20
40
60
80
100
120
140
DISCHARGE IN 1000 CFS



REV FEB. 1964

2 PLATE D-44



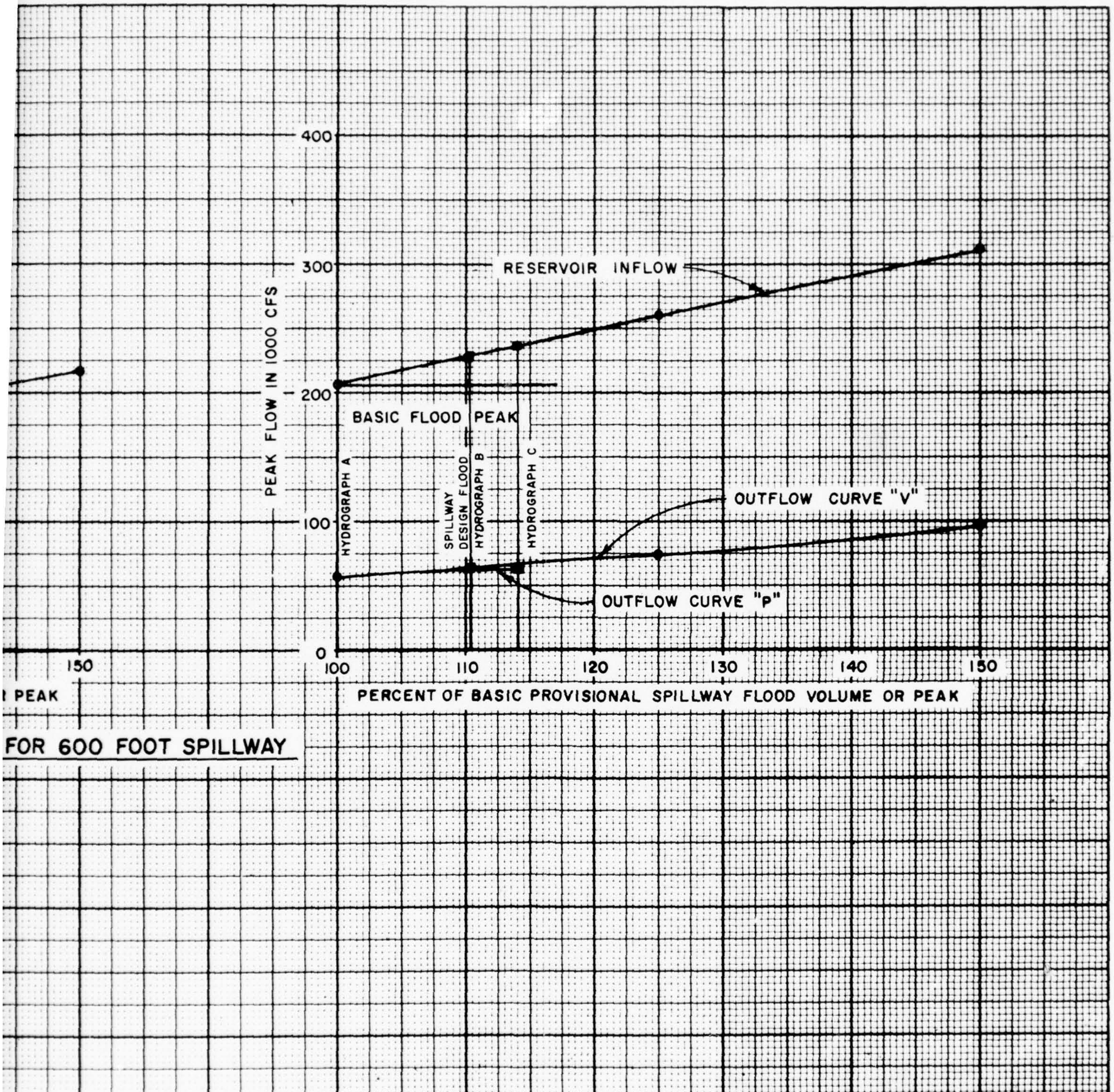
FOR 600 FOOT SPILLWAY

NOTE: CURVES "V" AND "P" REPRESENT RESULTS OF ROUTING HYPOTHETICAL SPILLWAY FLOODS FROM STARTING POOL ENVELOPE ELEVATION 550.0. WITH THE POOL ELEVATION BETWEEN 560 AND 551, OUTFLOW WAS LIMITED TO 1500 CFS (SPILLWAY PLUS CONDUIT). WHEN THE POOL REACHED ELEVATION 551, THE OUTFLOW WAS UNCONTROLLED OVER THE SPILLWAY AND THE CONDUIT GATES WERE OPENED IN A MINIMUM OF 12 HOURS.

LETTER "V" OF CURVE INDICATES VOLUME OF BASIC FLOOD INCREASED BY VARIOUS PERCENTAGES, THE UNIT HYDROGRAPH REMAINING CONSTANT; LETTER "P" INDICATES VOLUME OF BASIC FLOOD WAS RETAINED CONSTANT AND PEAK INCREASED BY VARYING THE UNITGRAPH OF BASIN AREA ABOVE THE HEAD OF THE RESERVOIR (AREA I) AS APPLIED TO THE TWO MAXIMUM 6-HOUR PERIODS OF RAINFALL.

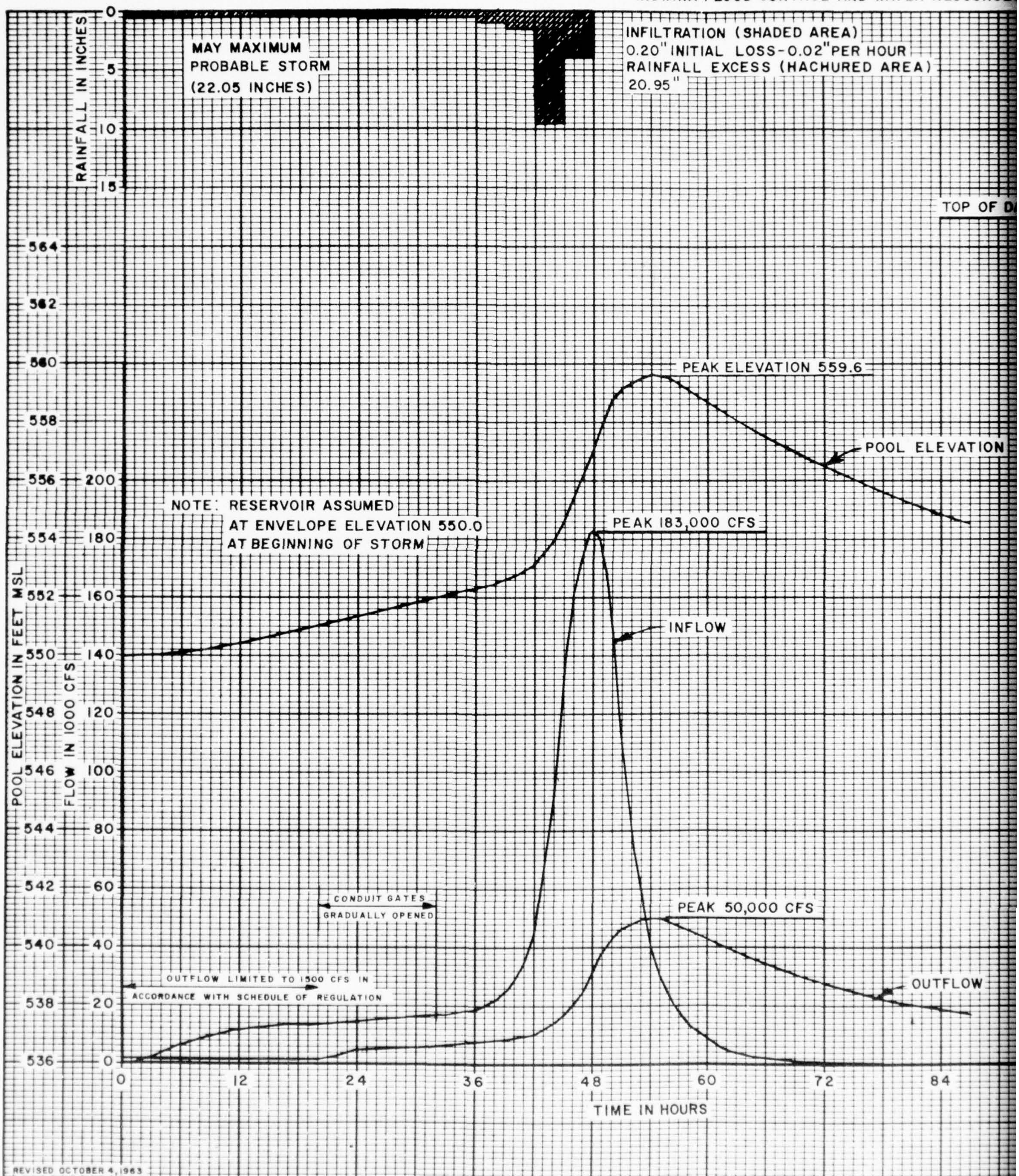
REVISED OCTOBER 4, 1963

ONTROL AND WATER RESOURCES COMMISSION



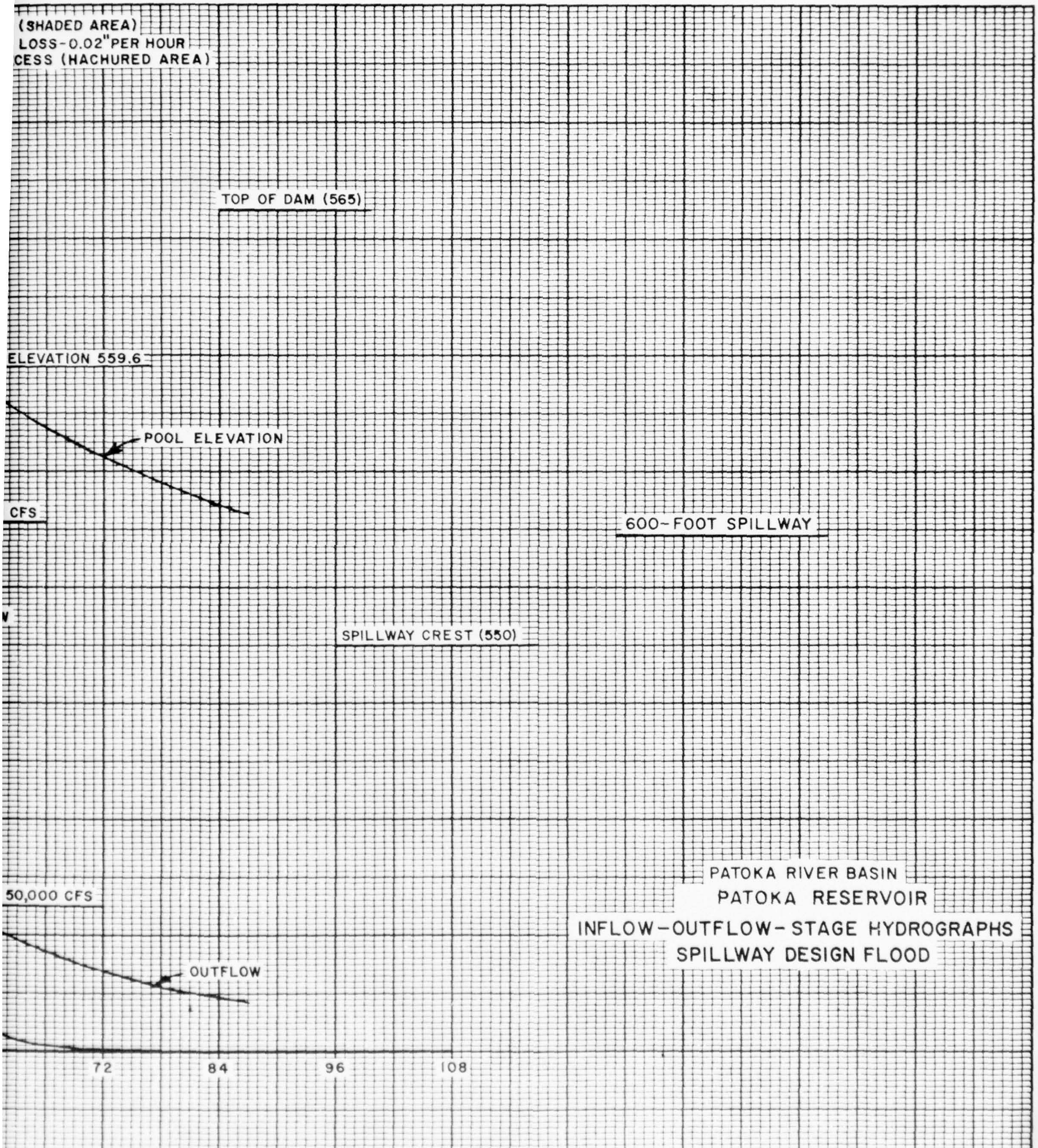
PATOKA RIVER BASIN
PATOKA RESERVOIR
PROVISIONAL SPILLWAY FLOOD
PEAK RESERVOIR ELEVATION
INFLOW - OUTFLOW CURVES

2 PLATE B-45



RAINFALL IN INCHES
0
5
10
15
MAY MAXIMUM
PROBABLE STORM
(22.05 INCHES)
INFILTRATION (SHADED AREA)
0.20" INITIAL LOSS-0.02" PER HOUR
RAINFALL EXCESS (HACHURED AREA)
20.95"
TOP OF DA
PEAK ELEVATION 559.6
POOL ELEVATION
NOTE: RESERVOIR ASSUMED
AT ENVELOPE ELEVATION 550.0
AT BEGINNING OF STORM
PEAK 183,000 CFS
INFLOW
CONDUIT GATES
GRADUALLY OPENED
PEAK 50,000 CFS
OUTFLOW LIMITED TO 1500 CFS IN
ACCORDANCE WITH SCHEDULE OF REGULATION
OUTFLOW
POOL ELEVATION IN FEET MSL
FLOW IN 1000 CFS
564
562
560
558
556
554
552
550
548
546
544
542
540
538
536
200
180
160
140
120
100
80
60
40
20
0
0
12
24
36
48
60
72
84
TIME IN HOURS
REVISED OCTOBER 4, 1963

OD CONTROL AND WATER RESOURCES COMMISSION



CORPS OF ENGINEERS

U.S. ARMY

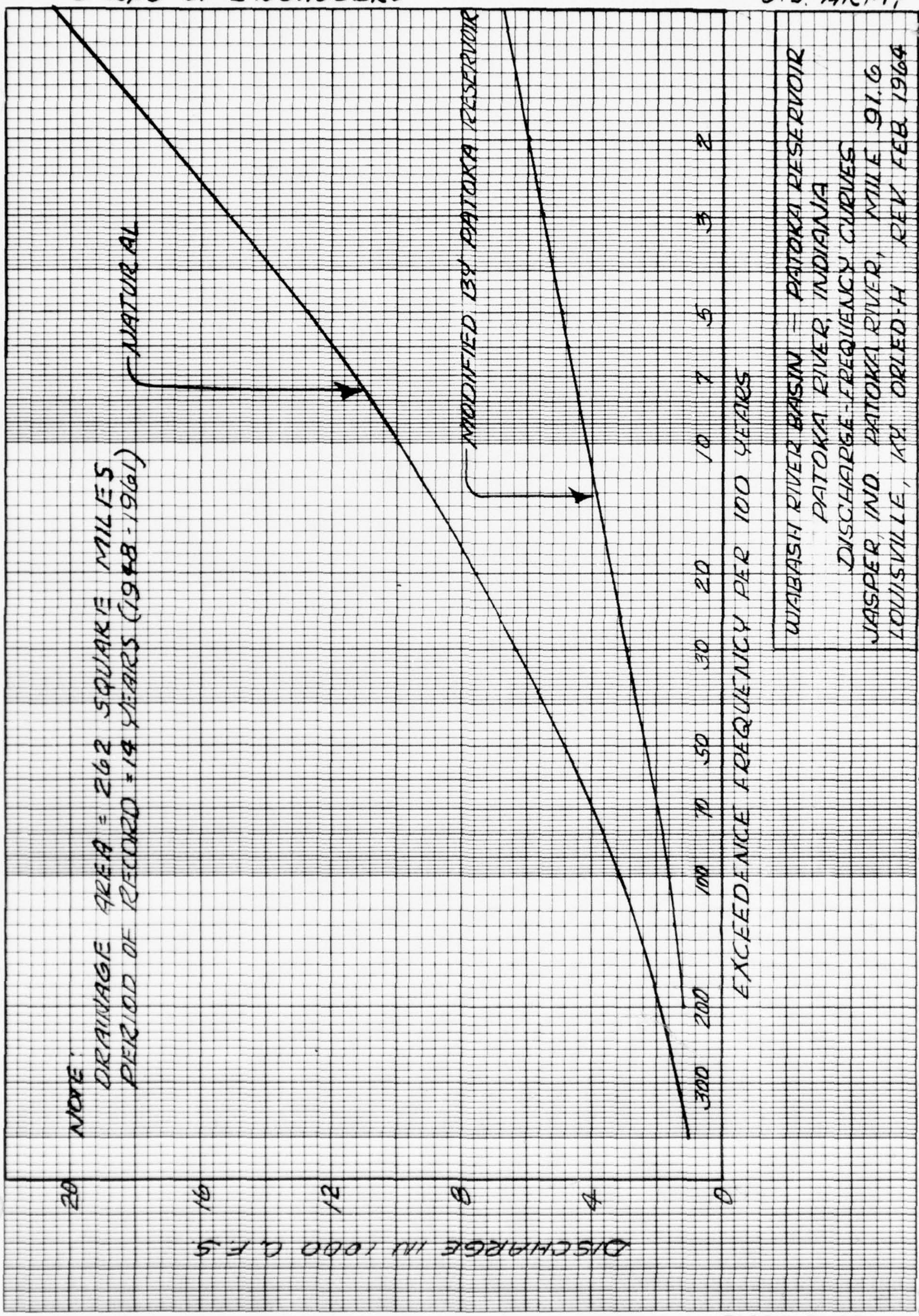
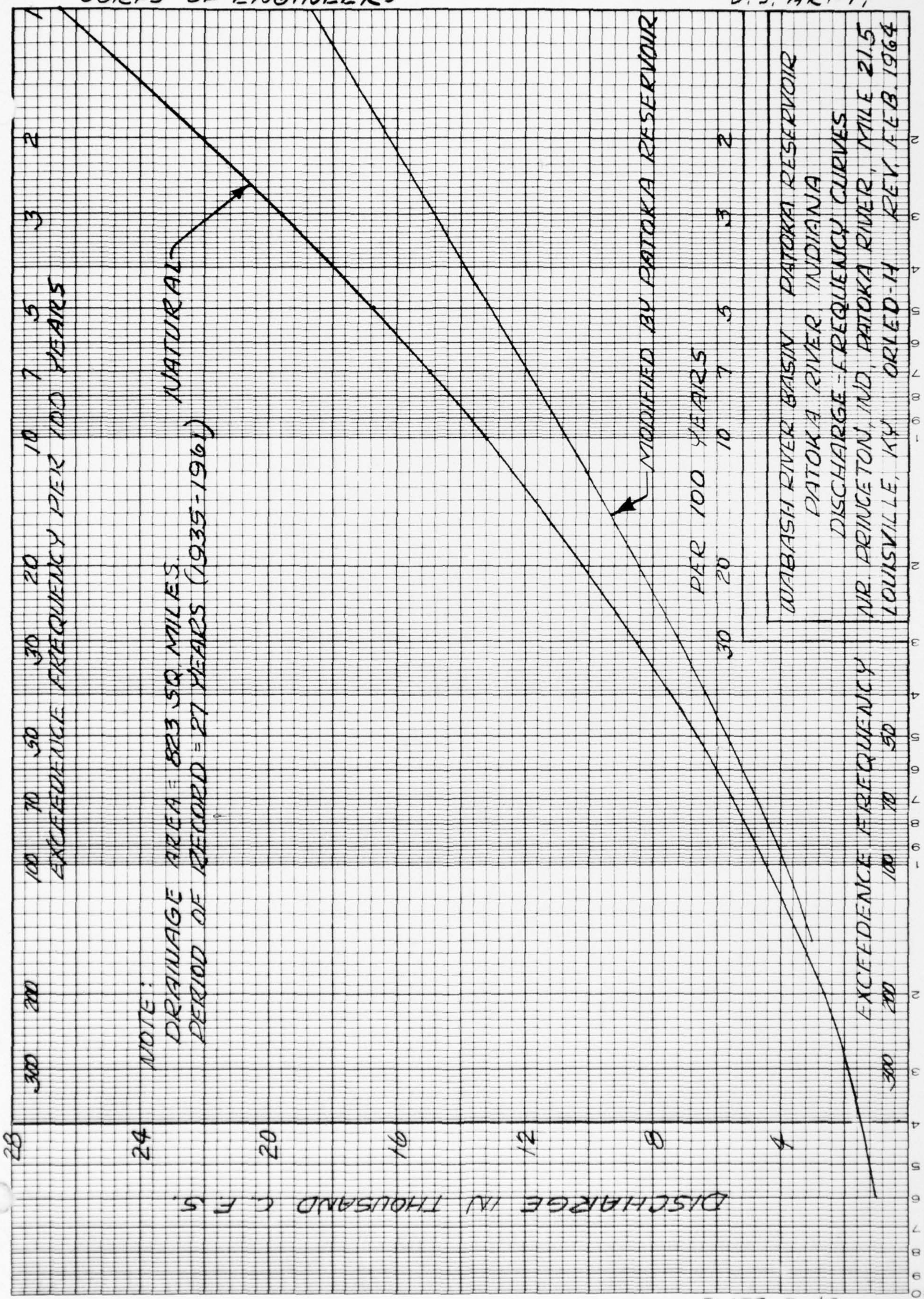
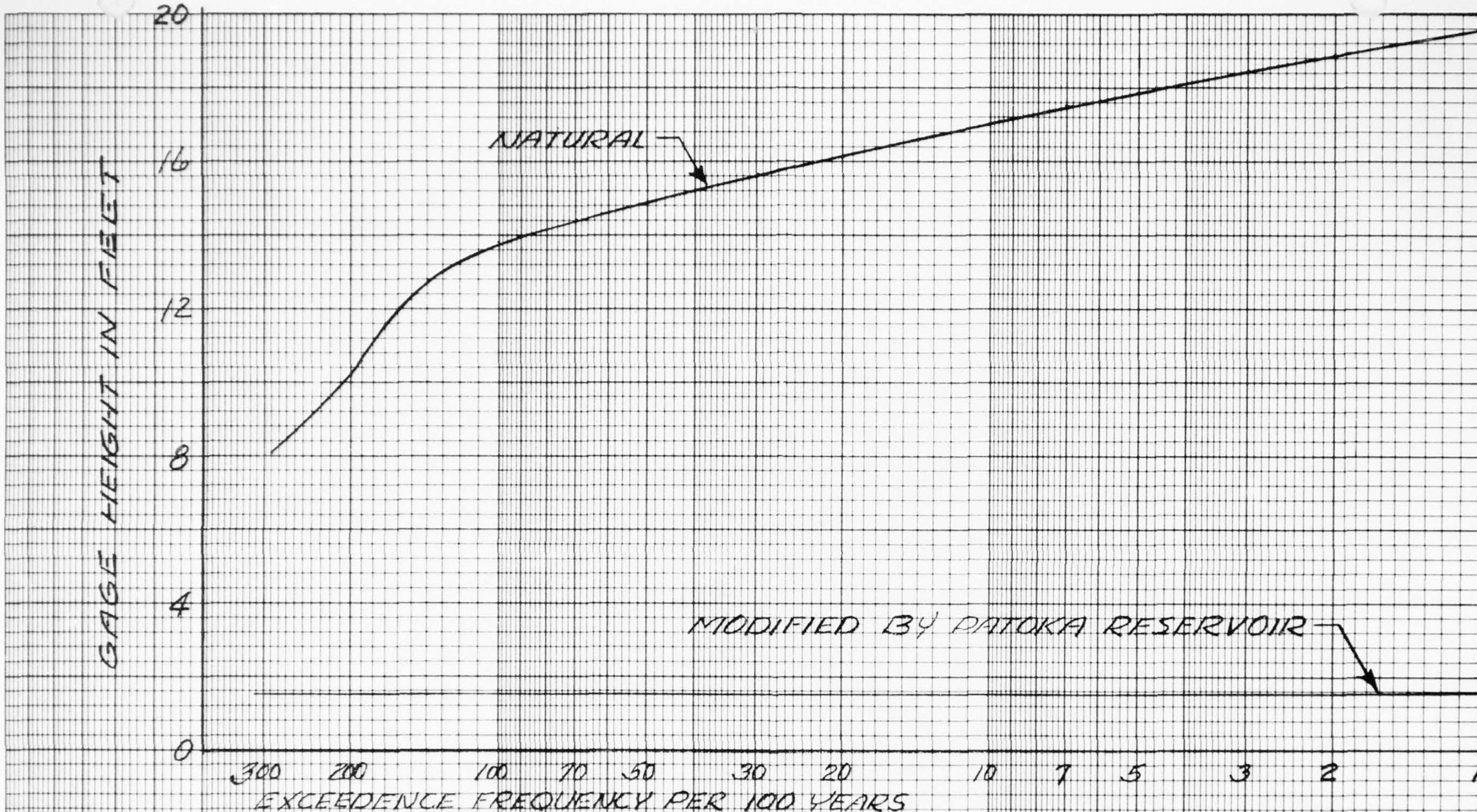


PLATE D-47

CORPS OF ENGINEERS U.S. ARMY



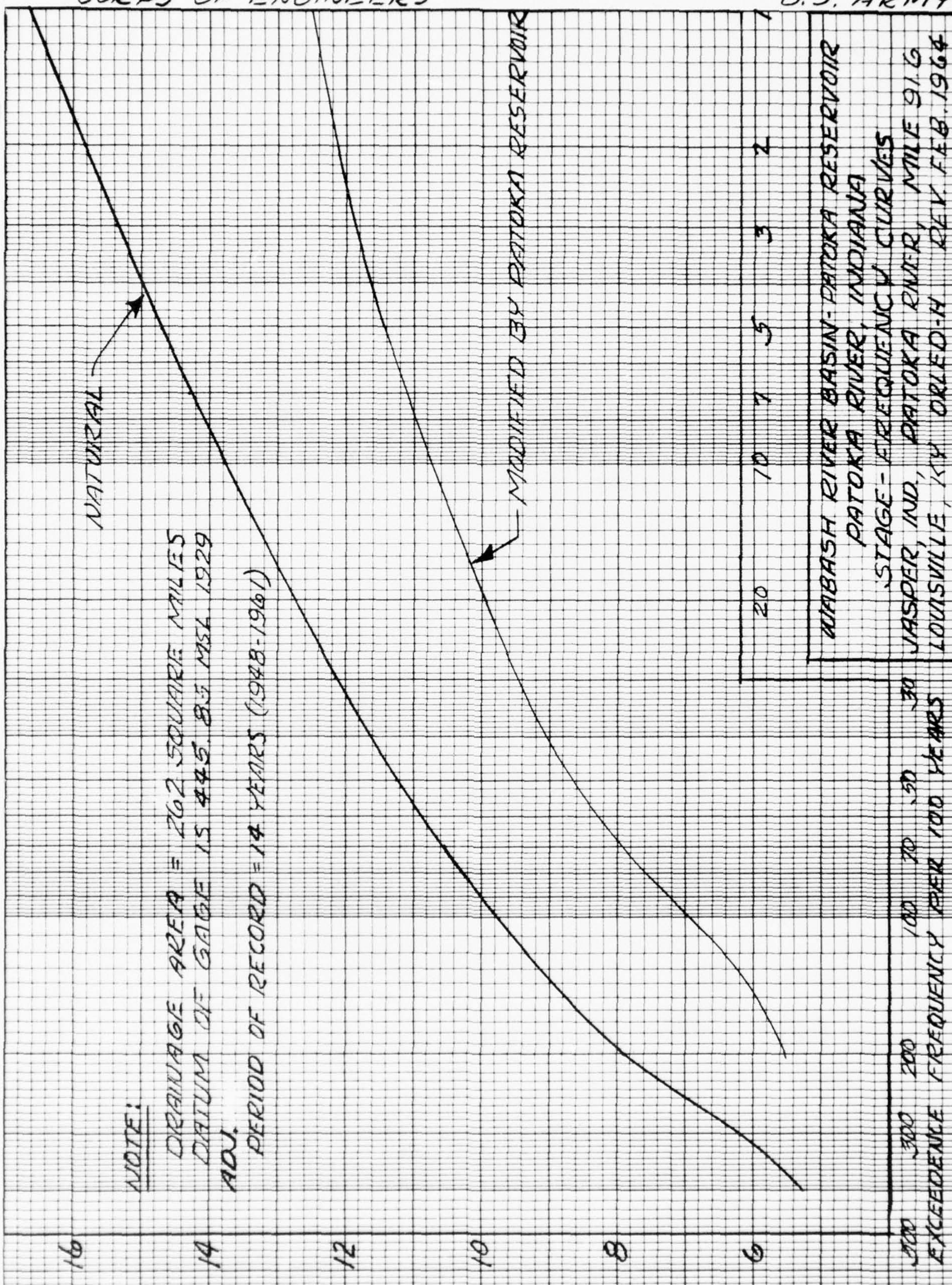


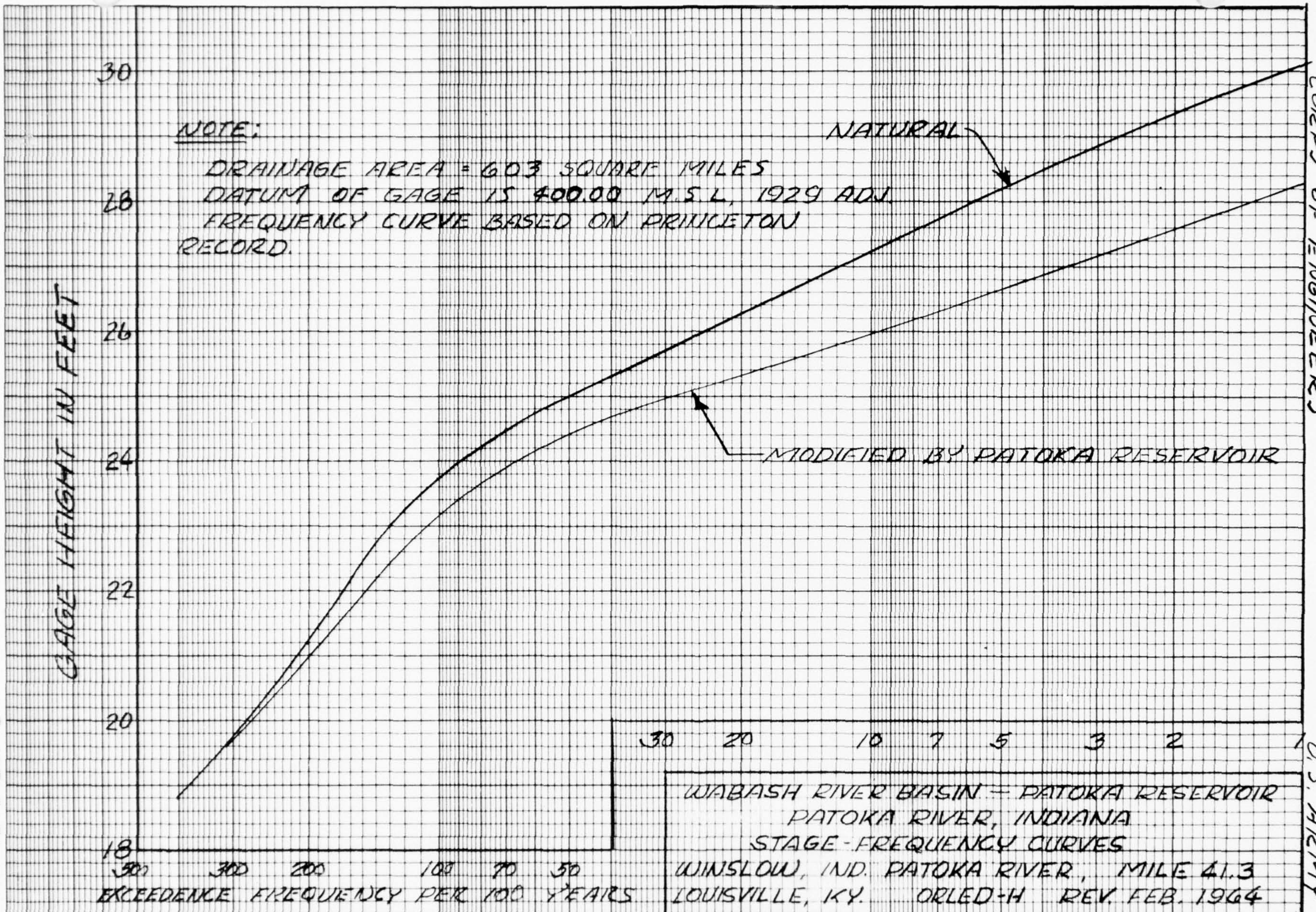
NOTE:
DATUM OF GAGE IS 477.00 FEET ABOVE M.S.L. 1929 GEN. ADJ.
DRAINAGE AREA = 171 SQUARE MILES.
FREQUENCY CURVE BASED ON JASPER RECORD

WABASH RIVER BASIN
PATOKA RESERVOIR
PATOKA RIVER, INDIANA
STAGE-FREQUENCY CURVES
NEAR ELLSWORTH, INDIANA
PATOKA RIVER, MILE 116.1
LOUISVILLE, KY ORLED-H REV. FEB. 1964

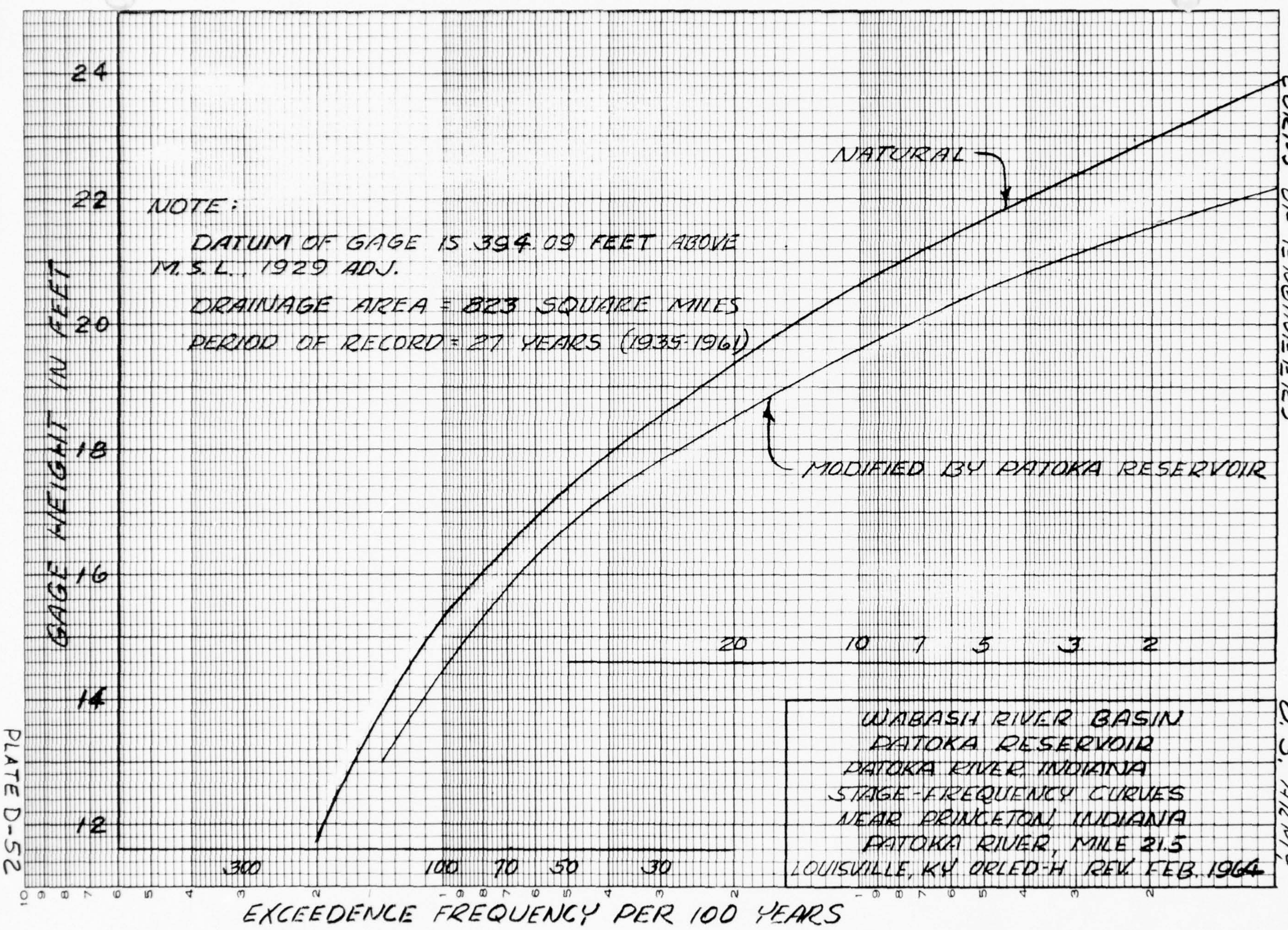
CORPS OF ENGINEERS

U.S. ARMY

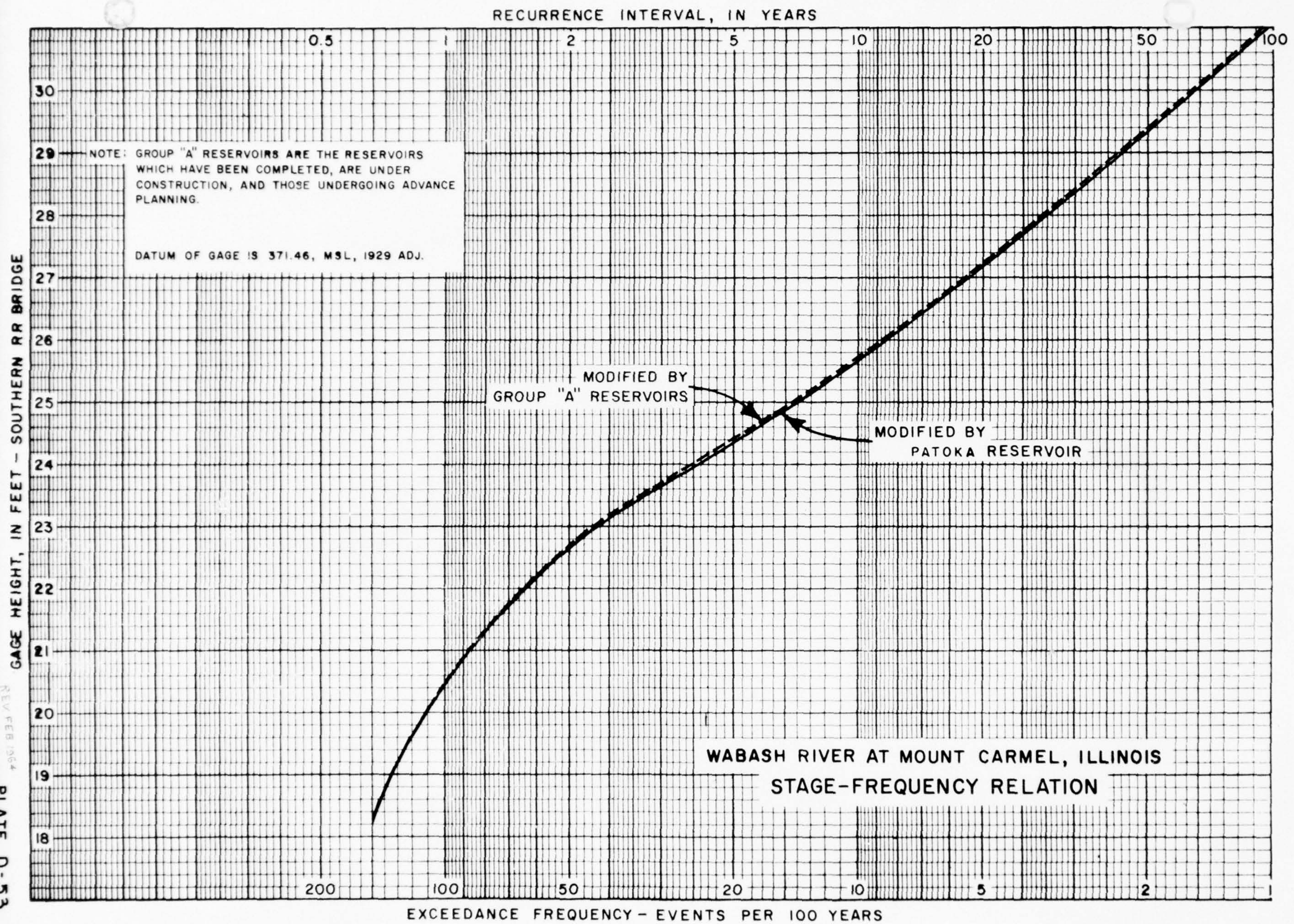

WABASH RIVER BASIN-PATOKA RESERVOIR
PATOKA RIVER, INDIANA
STAGE-FREQUENCY CURVES
JASPER, IND., PATOKA RIVER, MILE 91.6
LOUISVILLE, KY. ORLED-H REV. FEB. 1964
NOTE:
DRAINAGE AREA = 262 SQUARE MILES
DATUM OF GAGE IS 445.85 MSL 1929 ADJ.
PERIOD OF RECORD = 14 YEARS (1948-1961)
NATURAL
MODIFIED BY PATOKA RESERVOIR
GAGE HEIGHT IN FEET
6
8
10
12
14
16
EXCEEDENCE FREQUENCY PER 100 YEARS
500
300
200
100
70
50
30
20
10
7
5
3
2
1



CORPS OF ENGINEERS
U.S. ARMY
NOTE:
DRAINAGE AREA = 603 SQUARE MILES
DATUM OF GAGE IS 400.00 M.S.L. 1929 ADJ.
FREQUENCY CURVE BASED ON PRINCETON RECORD.
NATURAL
MODIFIED BY PATOKA RESERVOIR
GAGE HEIGHT IN FEET
30
28
26
24
22
20
18
500
300
200
100
70
50
30
20
10
7
5
3
2
1
EXCEEDENCE FREQUENCY PER 100 YEARS
WABASH RIVER BASIN - PATOKA RESERVOIR
PATOKA RIVER, INDIANA
STAGE-FREQUENCY CURVES
WINSLOW, IND. PATOKA RIVER, MILE 41.3
LOUISVILLE, KY. ORLED-H REV. FEB. 1964



CORPS OF ENGINEERS
U. S. ARMY
NOTE:
DATUM OF GAGE IS 394.09 FEET ABOVE M.S.L. 1929 ADJ.
DRAINAGE AREA = 823 SQUARE MILES
PERIOD OF RECORD = 27 YEARS (1935-1961)
NATURAL
MODIFIED BY PATOKA RESERVOIR
GAGE HEIGHT IN FEET
24
22
20
18
16
14
12
EXCEEDENCE FREQUENCY PER 100 YEARS
300
100
70
50
30
20
10
7
5
3
2
WABASH RIVER BASIN
PATOKA RESERVOIR
PATOKA RIVER, INDIANA
STAGE-FREQUENCY CURVES
NEAR PRINCETON, INDIANA
PATOKA RIVER, MILE 21.5
LOUISVILLE, KY ORLED-H REV. FEB. 1964



REV FEB 1964

PLATE D-53

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

INTERIM REPORT NO. 2
WABASH RIVER BASIN
COMPREHENSIVE STUDY
COVERING RESERVOIR SITES
ON
EMBARRASS RIVER, ILLINOIS
AND
CLIFTY CREEK AND PATOKA RIVER, INDIANA

APPENDIX E

GEOLOGY, SOILS AND MATERIALS

JANUARY 1964

INTERIM REPORT NO. 2
WABASH RIVER BASIN COMPREHENSIVE STUDY
INDIANA, ILLINOIS AND OHIO
COVERING RESERVOIR SITES ON EMBARRASS RIVER,
ILLINOIS AND CLIFTY CREEK AND PATOKA RIVER, INDIANA

APPENDIX E

GEOLOGY, SOILS AND MATERIALS

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TABLES

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Table of Contents (Cont'd)

LIST OF PLATES (Cont'd)

SECTION I - LINCOLN RESERVOIR, EMBARRASS RIVER

1. LOCATION OF PROJECT.

The Lincoln Reservoir Project is located in east-central Illinois, on the Embarrass River. The selected dam site (formerly Copper Cave site) is located at mile 103 on this stream near the northern boundary of Cumberland County.

2. PHYSIOGRAPHY.

The project area is located in the Till Plains of the great Central Lowland Province. These are mature plains whose rolling topography is concealed by a thick mantle of glacial overburden. In the uplands there is a little relief, the surface being undissected for large areas. The divides are flat and the uplands are traversed by low morainic ridges. The valleys, which begin as almost imperceptible grooves in the glacial till, are generally shallow and wide. The maximum relief between the Embarrass River and the adjacent uplands is about 150 feet, with the valley floor varying in width from one-quarter to two and one-half miles. Above the selected site, the greatest width is about a mile. This wide valley is probably due to glacial action, since it is too great to have been the work of the present stream. The river itself has many crooks and long tortuous bends, some of which have been straightened in the lower reaches by excavation of pilot cut-offs. The flat valley floor and the many meanders are an indication that maturity has been attained and a graded condition established.

3. REGIONAL GEOLOGY.

Soil Mantle. The bedrock topography is overlain by a thick mantle of drift deposited by the Illinoian and Wisconsin glaciers. On the prairies, the glacial drift is covered with variable but generally shallow thicknesses of loess and wind-blown fine sands. These loessial deposits are primarily alluvial, and secondarily aeolian, and were probably originally laid down in old glacial lakes. In the flood plain, thick deposits of silt, sand, and gravel of alluvial origin cover the bedrock surface. From these deposits, which were derived largely by erosion of the upland soils, were developed the rich alluvial soils of the lower Embarrass Valley.

4. BEDROCK STRUCTURES.

Geologically, the rocks in this area are all of the sedimentary origin and in the site area belong to the Newton Cyclothem of the Post Alleghenian of the Pennsylvanian period. They were derived from an area of erosion to the east, known as Appalachia. Prior to Pennsylvanian time, the interior of the coutry was a peneplain upon which was deposited the series of sediments which later developed into

shales, sandstones and limestones. In this area, the rocks are predominantly shales, with intervening beds of indurated clay, sandstone and a few thin beds of limestone and coal. These shales are soft to medium hard calcareous and carbonaceous clay shales, and were deposited in quiet and generally shallow waters and underlie the entire basin. Generally speaking, the upper strata are of fresh water derivation, while the lower part is of marine origin. The limestones generally consist of two strata, one beneath the uppermost layer of shale, and the other from 50 to 80 feet deeper, with intervening layers of shale and sandstone. The sandstones are not widespread sheet deposits like the shales but are interrupted and broken. This is a result of the nature of their deposition, which was probably along the shore lines of the ancient mid-continental sea. There is no apparent folding in this region, the rocks forming an almost flat monocline, which dips gently to the southwest.

5. GROUND WATER CONDITION.

Generally, the ground water table rises on a gentle gradient from the river. Static water stands at elevation 631± in the abutment holes. A brief resume of groundwater conditions in the Embarrass River basin as prepared by the U. S. Department of the Interior, Geological Survey is contained in Appendix F.

6. FOUNDATION EXPLORATIONS.

The bulk of the foundation investigations for Lincoln Reservoir was accomplished between 1939 and 1944 and presented in the Definite Project Report on Wolf Creek Reservoir, Illinois, dated 31 July 1945. Four additional core holes and four auger holes were drilled in October 1962. The graphic logs of all borings are shown on plates E-6 through E-16.

7. PRELIMINARY SITE SELECTION.

Five possible locations on the Embarrass were investigated and covered in the 1945 D.P.R. It was established in the D.P.R. that due to economics, storage and geology only the Copper Cave Site was considered feasible. The Copper Cave Site consists of 4 alternates, identified as 1-1, 2-2, 3-3, and 4-4 starting at the downstream end of a relatively narrow and deep valley for a distance of about 0.8 mile and progressing upstream. Discussion of the 4 alternates is given in Appendix IV, beginning with paragraph 11 of the Definite Project Report.

8. DESCRIPTION OF COPPER CAVE SITE.

The Embarrass River has cut through the glacial deposits in this area and has entrenched itself in a deep and moderately narrow valley. The flood plain through the site area varies from about 800 to 1,000 feet in width. The stream meanders from the right side to the left

side of the flood plain through the upper part of the site area and back again to the right side near the lower section. The river channel has an average width of about 125 feet and a depth of roughly 15 feet. The valley walls along the stream are deeply cut by many gullies and washes, some of which extend as much as one mile into the upland area. Except for this condition, the slope from the flood plain to the top lands is very steep, averaging between one on one and a half to one on three. Several isolated sections of slope from the top lands are as steep as one on one. Throughout the lower reach of this site area, a medium soft sandstone outcrops in the valley walls at a height of 30 to 40 feet above the flood plain.

9. FINAL SITE SELECTION.

Site 4-4 was selected in the Definite Project Report as being the more desirable location for the dam. The right bank abutments of all sites are quite narrow at spillway elevation 629. There are sand lenses in the glacial till thus it is reasonable to assume that leakage will develop through the abutment when the pool is at higher elevation. In view of past experience on the sites along the Wabash River in Indiana, it would be advantageous to select a location where the permanent pool would be contained entirely in rock. The friable poorly cemented sandstone can be tightened up with a grout curtain. In order to reduce leakage through the sand lenses in the abutment, the axis of any structure should be located near the upstream edge of point or promotory, so that an upstream impervious blanket or fill can be incorporated into the designed embankment. If necessary upstream gullies along the abutment would be cleaned and filled to seal off all sand lenses. A 5th alternate site, upstream from site 2-2, should provide a pool below the top of rock with maximum protection along the thin abutments. This proposed alternate axis would be 50 feet upstream on the right abutment and some 300 feet upstream on the left abutment. This 5th alternate site is the site of Lincoln Dam proposed herein. The following paragraphs relate to the proposed Lincoln Dam site and reservoir area.

10. FOUNDATION CONDITION AND PROBLEMS.

a. Dam. Plate E-4 is a geologic profile of the proposed dam site. The abutments are composed of glacial till with lenses of sand and gravel overlying a soft, fine grained, friable, poorly cemented, micaceous sandstone with shaly lamina. Top of the sandstone in the abutment varies from elevation 585 to 595. The probable leakage through the glacio-fluvial sand and gravel in the till was discussed in the preceding paragraph. Below the sandstone is a 20 to 25' thick silty to clay shale. When covered by the overlying sandstone in the abutments the shale is medium hard. In the valley the upper 15'± of the shale has been stripped off by erosion processes of the Embarrass River and is overlain by 20 to 25 feet of alluvial fine grained silty sand. The 6 to 9 feet of shale beneath the sand is very soft and weathered. A 40' wide cut-off trench will be necessary through the

sand across the valley. Six inch diameter drill holes will be necessary during the design exploration stages to determine whether the shale should be taken out in the cut-off trench.

b. Spillway. The left bank spillway will have its crest in glacial till (impervious silty sandy clay with traces of gravel). The spillway will be inclined with a flat grade and will discharge into Clear Creek. Plate E-5 is a geologic profile of the spillway. Side slopes will be 1 on 3 with a crest width of 100 feet. A 50 foot wide control structure is required.

c. Outlet Works. Present plans are to found the outlet works in the left abutment in the silty to clay shale. Invert elevation for the conduit is 538. A two foot thick gravel layer will be placed around this conduit from the intersection of the sloping drain to the stilling basin.

d. Grouting. A single line grout curtain will be required in the abutments and across the valley. The grout curtain will extend from station 0+00 to 24+00. Between stations 0+00 and 6+00 the grout curtain should extend from top of rock to elevation 540. Between 6+00 and 8+00 would be a transition zone from the abutment to valley section. The valley section between station 8+00 and 18+00 would extend below the limestone to elevation 500 in shale. Between 18+00 and 19+00 would be valley to abutment transition zone. From 19+00 to 24+00 the grout curtain would extend from top of rock to elevation 530 which would be through the sandstone and into the shale.

11. EMBANKMENT.

The embankment will be constructed of impervious soil obtained from other features of construction and from the borrow areas. The planned embankment section as shown on plate E-3 will have a 30 foot top width, will be symetrical with a 1 on 2.5 side slopes from top of dam at elevation 648 to spillway crest at elevation 629, 1 on 3 side slopes from 629 to 570 and 1 on 3.5 slopes below elevation 570. The upstream slope will be protected with 18 inches of riprap on 9 inches of bedding from elevation 579 to top of dam. Downstream riprap will be placed up to the elevation of maximum tailwater. A 40 foot cutoff to rock will be built across the valley and in the abutments until a depth of 20 feet of soil is reached in the abutments. When this depth is exceeded then an inspection trench will be constructed for the remainder of the structures. The existing soil foundation will otherwise be left in place. Internal drainage of the embankment will be by sloping and horizontal drains located as shown on plate E-3. Top of the sloping drain will be at elevation 629. The width will be 5 feet. The horizontal drain will be two feet thick and will be placed directly on the soil foundation after stripping of organic soil. Downstream from the sloping drain a compacted random fill zone is detailed to place any non-organic material

from required excavation which is not suitable for placement in the impervious fill zone. The structure as outlined above is believed safe based on comparisons with previous construction.

12. SOURCES OF CONSTRUCTION MATERIALS.

Table 1 below shows the origin and disposition of major quantities of construction materials required to build the embankment. Borrow areas are located high in the abutments, as shown on plate E-2, where impervious clay till soils are available to construct the embankment. Gravel pits are located within 5 miles of the project which can produce material suitable for the drain and bedding requirements and fine aggregate for concrete mixes. No active limestone quarries are located near the dam site. Riprap and coarse aggregate must be obtained from commercial limestone quarries such as those located near Greencastle, Indiana; East St. Louis and Kankakee, Illinois. These sources are 100 miles from the dam site. Testing of this source will be required. Portland cement is available from plants located near Mitchell and Greencastle, Indiana and Chicago, Illinois. The Greencastle source is the nearest.

TABLE 1

LINCOLN RESERVOIR

ORIGIN AND DISPOSITION OF CONSTRUCTION MATERIALS

Feature	Sub-Feature	Quantity Cu. Yds.	Origin & Disposition
Spillway	Excavation Earth	60,400	Place Suitable in Embankment - Waste all other.
Conduit & Channels	Excavation and Earth	51,800	Use Suitable in Embankment - and around conduit.
	Excavation, Rock	10,800	Place in embankment.
Embankment	Top Soil Stripping	32,700	Haul to Waste Area.
	Core Trench Excavation	46,300	Use suitable in Embankment - Waste all other.
	Borrow	1,253,000	Obtain from borrow Areas.
Misc. Materials	Riprap	19,700	Obtain Commercially
	Bedding	9,800	Obtain Commercially
	Drain Material	27,500	Obtain Commercially

SECTION II - CLIFTY CREEK RESERVOIR, CLIFTY CREEK

13. PHYSIOGRAPHY.

The reservoir area is located in the Muscatatuck Region Slope physiographic province of Indiana near the southern limits of the Wisconsin glacier. Structurally the area is located on the western flanks of the Cincinnati arch with a regional dip of 25 to 35 feet per mile to the west; dominant joint patterns are N10W, N20E, N50E, N65E.

14. BEDROCK.

Bedrock in the area in ascending order is as follows:

a. Geneva Dolomite. Elevation 716 (top of rock) to Elevation 688 base of formation. Tan, medium hard to soft, weathered, fine grained, sugary textured dolomite, buff chert in the upper portion, jointed, 0.5' to 2.0' bedding. The rock is poorly cemented and solution channels should be expected throughout. Depth of primary weathering bottoms out at the base of the Geneva Dolomite.

b. Louisville Limestone. Five feet thick - Elevation 688 to 683± - a five foot thick gray fine grained crystalline, dolomitic limestone, medium hard to hard with 1/4" shale seams along bedding plains. The lower one foot is shaly limestone to calcareous shale transition zone to Waldron shale below; 1.0' bedding.

c. Waldron Shale. Seven feet thick - Elevation 683 to 676 calcareous, medium hard, 0.5' bedding; gray. The shale has a weathered zone at its base.

d. Laurel Dolomite. Twenty-four feet thick, Elevation 676 to 652. Gray, fine grained crystalline limestone, hard, stylolitic, buff chert nodules in upper 10 feet, dolomitic, jointed with weathered seams, some shaly lamina along bedding plains, in lower 10 feet, 0.5' to 2.0' bedding.

e. Osgood Formation. Light gray to gray, fine grained crystalline limestone, hard, with 1/8" shale lamina. Becomes more shaly with depth. Total thickness drilled was 20 feet in DC-5 which bottomed out in the Osgood. Top of formation Elevation 652.

f. Elevations on above formations were taken from the right abutment. The elevations will vary since the apparent dip is 10 feet per mile to the northwest or from the left bank to the right.

g. The Falls located up Falls Fort are due to the undercutting of the Waldron Shale which outcrops at Elevation 700 beneath the falls.

15. Prior to the deposition of glacial deposits erosion channels were cut in the bedrock surface producing a highly uneven top of rock surface. Old erosion channels were encountered in both abutments where pre-glacial streams had cut through the highly weathered Geneva Dolomite, Louisville Limestone, Waldron Shale and bottomed out in the Laurel Dolomite. It was on this uneven surface that glacial deposition took place.

16. GLACIAL DEPOSITS.

Glacial deposits in the dam site area are gravelly silty clay glacial tills, tan (leached) to blue gray with 2 to 4' thick highly compact gravelly sands presumably lenticular in distribution. The clay tills are relatively impervious. With the exception of DC-3 all borings in the abutments encountered clay till lying immediately on bedrock. The glacial deposits are Wisconsin in age.

17. ALLUVIAL DEPOSITS.

In the narrow Clifty Creek Valley there is 15 feet of alluvial deposits resting on bedrock. The alluvial deposits consist of gravelly sand at the base grading up into silty sand which is overlain by 5 feet of sandy clay at the surface.

18. TOPOGRAPHY AND DRAINAGE.

The uplands have typical flat lying ground moraine topography with broad U shaped ravines and gentle gradients. Near the major streams where the 40 feet ± of glacial till have been removed steep slopes and gradients have developed on the bedrock surface. Drainage is both external and internal. There are springs along the bedrock-till contact and also high elevation springs in the glacial till in the uplands.

19. FOUNDATION CONDITIONS AND PROBLEMS.

a. Buried Channels. Two buried channels were encountered during subsurface exploration. Plate E-19 shows the relative location of the channels. The left bank buried channel has top of rock at elevation 666.1. The channel is filled with impervious gravelly sandy clay till and static water in DC-8 stood at elevation 743.8. The exact width and alignment is not known since only one hole was drilled in its location. However on the inlet end of the channel in Fall Fork it is approximately 700-800 feet wide. Top of rock elevations and the approximate channel alignment are marked on the plan, plate E-17. No serious leakage problems are anticipated for the left bank channel. The right bank buried channel located in the vicinity of DC-3 gives the geologic profile the appearance of a "false front." This channel is approximately 700 feet wide at the inlet end. Top of rock in DC-3 was 673.1 compared to the 704 top of rock in the right abutment approximately 500 feet to the southeast.

The channel is filled with 20 feet of brown, sandy, gravelly clay with weathered rock fragments immediately on top of rock; the lower 5 feet being sandy clayey gravel. This 20' interval appears to be fairly impervious. It appears to be more of a "residual slump" rather than a glacial deposit. Overlying the "residual slump" is 38 feet of impervious brown and gray, firm sandy gravelly clay. Ground water is low in the channel elevation 669.5 and the right abutment, elevation 669.8. Water level in Clifty Creek was elevation 665±. A brief resume of ground water conditions in the Clifty Creek basin, as prepared by the U. S. Department of the Interior, Geological Survey, is contained in Appendix F. Extensive explorations will be required to outline both channels, however, preference should be given to the right bank buried channel to determine if the "residual slump" is impervious in areal distribution and to determine if a sufficient semi-impervious cover exists to prevent seepage.

b. Dam and Dike. The embankments will be constructed of glacial till. Maximum height of the dam will be approximately 90 feet. A symmetrical section is planned as shown on the attached drawing. Top width of dam will be 30 feet. Slopes will be 1 vertical on 2-1/2 horizontal above elevation 730 and 1 vertical on 3-1/2 horizontal below this elevation. Top of dam is at elevation 753, spillway crest is 717.0 and permanent pool is at elevation 705. The upstream slope will be protected with 18 inches of riprap over 9 inches of bedding material from elevation 700 to top of dam. Riprap protection will be provided on the downstream slope up to maximum tailwater. A five foot horizontal width filter drain will be provided with a top elevation at 745. Discharge will be into a two foot filter drainage blanket placed on the downstream foundation. A 30 foot wide cutoff trench to bedrock will be constructed in the steep valley abutments and through the valley. The contacted bedrock will be hand cleaned and slush grouted. Dental concrete will be used where slush grout is not suitable for filling larger irregularities. A 10 foot base width, 6 feet deep inspection trench will be utilized in the high abutments when the depth of soil exceeds 20 feet. Pressure grouting will be performed as outlined in Paragraph 20 below. The maximum height of the dike will be approximately 8 feet. Crown width will be 12 feet with symmetrical side slopes of 1 vertical on 2.5 horizontal.

c. Spillway Investigations. Two holes were drilled in potential spillway sites. DC-1 in the right bank had top of rock at elevation 704.2. Overlying rock is glacial till (sandy, gravelly clay, very firm) with very compact lenses of sand. DC-8 in the left bank has top of rock at elevation 666.1 which is overlain by very firm glacial till. Blow counts in the vicinity of an uncontrolled spillway crest, elevation 730 varied from 166 to 832. These are blows per foot with a 325 pound hammer and an 18" drop. Foundation conditions would be similar in both sites; and both would have the glacial till for a foundation at the spillway crest. A gated spillway adjacent to Clifty Creek would be founded in the cherty fine grained crystalline limestone interval of the Laurel Formation, which will make a sound foundation.

Rev 9 Mar 1964

20. RESERVOIR TIGHTNESS AND GROUND WATER CONDITIONS.

Very little ground water information was obtained from farms in the area. The wells in the uplands obtain water from thin sand lenses in the glacial till and bedrock. The most reliable ground water information was obtained from drill holes. Ground water readings in drill holes were made with overburden cased off. In DC-8 drilled in the left bank drainage divide static water was encountered at elevation 743.8. DC-1 in the right bank drainage divide had static water at elevation 724.8. This compares with static water in a farm well 700 feet west of DC-1 of elevation 726. A potential zone of leakage is in the right abutment. Ground water is low in DC-4, elevation 669.8 and DC-3, elevation 669.5. Also drill water return was lost in DC-2 in a void at elevation 662.8, in DC-3 along a weathered bedding plain at elevation 665.9 and in DC-5 in a mud filled void at elevation 666.5. In FC-4A drill water return was lost in the weathered dolomite at elevation 695.6 and any lower water loss was not observed. Some solution was noted at the top of the Laurel Formation at the base of the Waldron Shale in DC-4 and DC-2. Grouting would be required the full length of the dam from top of rock to elevation 650.

21. SOURCES OF CONSTRUCTION MATERIALS.

Table 2 following shows the origin and distribution of all major construction materials. Both impervious and pervious borrow can be obtained within the reservoir area in the Fall Fork Valley upstream from the dam and dike. Natural sands and gravels for drain and bedding materials and sands for fine aggregate are available from sources near Columbus, Indiana. A haul of approximately 10 miles is required. Three limestone quarries are located within a 17 mile radius of the damsite. These quarries can produce riprap and coarse aggregate for portland cement concrete. A complete testing program will be required for all sources.

22. There are no mineral resources which will be flooded by the reservoir.

TABLE 2

ORIGIN AND DISPOSITION OF CONSTRUCTION MATERIALS

CLIFTY CREEK RESERVOIR

Feature	Sub-Feature	Quantity Cu. Yds.	Origin & Disposition
Concrete Section	Excavation Earth Structure & Channels	58,000	Use Suitable in Embankment - Waste all Other Material.
	Excavation Rock Structure & Channels	20,000	Place in Embankment.
Embankments	Stripping	45,000	Haul to Disposal Area.
	Excavation, Common	37,000	Place Suitable in Embankment - Waste all Other.
	Excavation, Borrow	730,000	Obtain from Borrow Areas.
Misc. Materials	Riprap	22,000	Obtain Commercially
	Bedding Material & Drain Material	56,000	Obtain Commercially
	Derrick Stone	1,500	Obtain Commercially
	Spalls	300	Obtain Commercially

SECTION III - PATOKA RESERVOIR, PATOKA RIVER

23. LOCATION.

The Ellsworth Dam Site is located on the Patoka River, north 1/2 section 14, T 1 S, R 3 W, in Dubois County, on the Cuzco, Indiana Quadrangle.

24. GENERAL GEOLOGY.

The proposed site is located in the Crawford uplands. The topography is rugged, characterized by highly dissected ridges with dendritic drainage. There is about 260 feet of relief. The Patoka Valley is broad and flat with a meandering river. The width of the valley varies from 1,000 to 3,000 feet. Although the area is not within the glacial boundaries, glacial melt waters have cut a deep bed-rock channel about 64 feet below the present flood plain. The reservoir area is composed of the Chester series of sandstone, shale and limestones, Mississippian in age capped by Pennsylvanian sandstones and shales. The regional structure dips 42 feet per mile to the west and southwest. The observed joint patterns in the dam site area are N-S and E-W. Width of jointing varies from 3 to 20 feet with an average of 10 feet.

25. INVESTIGATIONS PERFORMED.

a. Preliminary reconnaissance in the reservoir area was made by the geologists for the Indiana Flood Control and Water Resources Commission. The proposed site was selected by the Flood Control Commission. A seismic and resistivity profile was made along the centerline and 1600 feet upstream from the centerline. These profiles indicated a 60' deep buried valley. One deep hole was drilled by the Indiana Geological Survey in the right bank drainage divide which gave a complete section of all formations which were encountered in the dam site area. Based on the information presented by the Flood Control Commission, it was decided that the preliminary investigation by the Corps of Engineers should concentrate primarily on the ground water and relative water tightness of the dam abutments and the foundation for the dam and spillway. Pertinent data for the reservoir is as follows:

Top of Dam	El. 565
Flood Control Pool	El. 550
Conservation Pool	El. 536

b. The Corps of Engineers have drilled ten core holes. All holes were driven to rock using a solid barrel soil sampler with a 350# hammer and an 18" drop. Rock was cored with a NXM double tube core barrel. Four holes were drilled along the narrow right abutment. Two holes DC-3 and DC-4 had well points and 2" pipe installed to serve

as ground water observation wells. Two holes were drilled on the left abutment and three holes were drilled on the right bank flood plain. All drill holes are referenced to the base line put in the field by the Flood Control Commission. A plan showing the base line and hole locations is attached. A proposed hole for the dike was not drilled due to depletion of funds. All abutment holes were drilled at an angle with the vertical.

c. At the completion of foundation investigations by the Corps, the Indiana Flood Control and Water Resources Commission, in conjunction with the Indiana Geological Survey, drilled a total of 23 holes in the right bank drainage divide, left abutment and dike area. The holes were rock bitted down, filled with water and electric logged. The water level was carefully checked and is recorded on plate E-27. The electric log data is not complete and is not included in this report. Plate E-27 is a geologic profile by the Flood Control Commission based on drill cuttings. Drill logs for the left bank and dike area were not available for this report.

26. GEOLOGY OF THE SITE.

a. Topography. As stated before the topography is rugged, with dendritic drainage. Relief is approximately 260 feet varying from elevation 490 in the flood plain to 750 in the drainage divides. The tributary systems adjacent to the Patoka Valley have low gradients and wide valleys. It is possible that the tributaries have deep buried valleys which have gradients adjusted to the bedrock valley under the Patoka River Valley.

b. Description of Bedrock. Bedrock in the area includes the Upper, Middle and Lower Chester Series sandstones, shales and limestones which are overlain by Pennsylvanian sandstones and shales. Descriptions of the formations in descending order are as follows:

Pennsylvanian:

Mansfield Formation: Sandstones and shales. Top of hills to elevation 630±.

Mississippian

Tar Springs Formation: A fairly well cemented sandstone and calcareous shale. Base of the formation varies from elevation 580 in the right bank drainage divide to elevation 550 in the dike area. Top of the formation is 630± in the right bank drainage divide.

Glen Dean Limestone: A gray, hard, fine to medium grained, crystalline limestone. Thickness varies from 14 feet on the right abutment to 30 feet on the left abutment. It should be noted that where the Glen Dean thickens on the left aubtment, the underlying Hardinsburg and Golconda Formations thin. The cumulative thicknesses of all three formations are 92-94' on both sides. One sink hole was

noted in the Glen Dean Limestone between stations 19 and 20. Base of the Glen Dean varies from elevation 570 in the right bank drainage divide to elevation 525 in the dike area. A cave is located approximately 2500 feet downstream from the dam on the west side of the left abutment. A spring in the cave, which bottoms out on top of the Hardinsburg shale, occurs at elevation 509. There is a slight northwest pitch to the strata in this area. During the months of October and November in 1962, the spring flowed at a rate of 8 gallons per minute. The spring is used as a source of stock water for farmers in the community. The cave has been explored by local people for a distance of 400 feet back into the hill where they were stopped by a rock fall. Since it is being used as the water source for the owner, no exploring was allowed during the preliminary investigation. It is apparent that solution penetrates the entire thickness of the Glen Dean Formation. On the right bank, the Glen Dean is above the proposed spillway crest of elevation 550 whereas in the dike area the base of the Glen Dean is elevation 503, some 47 feet below spillway crest and 33 feet below proposed permanent pool.

Hardinsburg Formation: The Hardinsburg Formation is composed of medium hard calcareaous shale, fairly well cemented calcareous sandstone and soft, slickensided indurated clay. The thickness varies from 32 feet on the right abutment to 25 feet on the left abutment. Numerous old slides are evident in this formation on the left abutment. No slides were noted on the right abutment. Base of the formation varies from elevation 530 on the right bank drainage divide to elevation 470 in the dike area.

Golconda Formation: The Golconda Formation is composed of two distinct lithologic units. The upper unit is a fine to medium grained crystalline limestone which has a thickness of 29 feet in the right abutment and 21 feet in the left aubtment. The limestone grades downward into a gray calcareous shale with a 1 to 7' thick indurated clay near the base. The lower unit varies in thickness from 20 feet in the right abutment to 17 feet in the left abutment. The Golconda limestone is exposed along the right abutment. There has been considerable solution along the joints where exposed. The joint pattern is N-S and E-W. Spacing of joints varies from 3 to 20 feet with an average of 10 feet. Numerous springs along the toe of the right abutment appear to bottom out on top of the Golconda Shale. Elevation of the springs is approximately 495. In DC-1, drill water circulation was lost at elevation 515. The water came out in a spring at elevation 495 at the toe of the hill. In the Indiana Geological Survey hole further back in the drainage divide, drill water return was lost at the top of the Golconda limestone, elevation 525. In the left abutment, in DC-7, drill water return was lost at elevation 485, near the base of the Golconda limestone. It was evident from exposures in the field that there had been considerable solution where the cover above the Golconda limestone was thin. Based on the drill holes, it appears there has been solution in the Golconda limestone where there is

thick cover. Thus the relatively impervious Hardinsburg Formation must be highly jointed, allowing free water movement from above.

Big Clifty Sandstone: Gray to white, very fine grained, friable to fairly well cemented sandstone. This formation does not outcrop in the project area. The thickness varies from 40 feet in the right abutment to 35 feet in the left abutment. Top of the sandstone in the right abutment is elevation 475.

Beech Creek Limestone: A fine to medium grained crystalline limestone. The lower 4 feet are argillaceous. It appears that the deep bedrock channel has bottomed out on top of the Beech Creek Limestone at elevation 430.

West Baden Group - Elwren Formation: Reddish brown, medium hard calcareous shale and indurated clay. Approximate thickness of 23 feet.

c. Description of Overburden. (1) Valley. The 64 feet of valley alluvium is primarily fine compact sand. There is some organic material in the sand. Overlying the sand is 4-1/2 feet of sandy silty clay. Immediately overlying bedrock is 11 feet of sandy, gravelly, clayey silt.

(2) Abutments. The gentle right abutment has 12 to 20 feet of residual sandy clay. The steep left abutment has 5 feet of residual sandy clay on the side slopes. The left abutment has a fairly well developed clay and gravel terrace at elevation 500.

27. FOUNDATION CONDITIONS.

a. Valley. The alluvial sand in the valley is compact and relatively impervious. Water content in the sand ranges from 21 to 28 percent, which indicates a fine sand. The top 5 feet of silty clay will be stripped under the dam. To limit leakage, relief wells should be installed at the downstream toe of the dam and a 6 foot thick impervious blanket placed from the upstream toe to 500 feet upstream from the dam.

b. Solution. Solution in the Glen Dean and Golconda Limestones has been discussed. Both of these limestones can be expected to have large solution channels that penetrate the entire abutments and the reservoir rim. The deep bedrock channel which had a base level of elevation 430± undoubtedly aided in the solution process of these limestones. Thus the abutments will require grouting into the Golconda Shale.

c. Numberous old slides were noted on the left abutment, primarily in the Hardinsburg Formation. A conduit on the left bank would be subject to slides from above. The conduit should be notched

into the right abutment. Top of the Big Clifty Sandstone in the right abutment is elevation 475. The sandstone is hard, fairly well cemented and will make a good foundation for the conduit. Invert elevation for the conduit is 481.1.

d. Spillway. The spillway will be located in the vicinity of station 20 as shown in plan on plate E-23. The crest will be in indurated clay of the Hardinsburg Formation as can be seen on the geologic profile of the dam and spillway, plate E-25. The upper portion of the spillway rock cut will be in the Glen Dean Limestone. Large mud seams should be expected in the limestone but where it is unweathered, the limestone will be sound and could be used for facing on the dam. Where exposed to weathering, the indurated clay at the crest will completely break down. A 50-foot wide concrete sill will be required at the crest to provide a constant 550 elevation. Spillway excavation will have one horizontal on 4 vertical slopes in bedrock and 3 horizontal on one vertical slope in soil. A 10-foot berm will be required at top of rock.

e. Dike. Plate E-26 shows a geologic profile of the dike based on boring made by the Indiana Flood Control and Water Resources Commission. Drill logs were not available and the information is based on verbal communication with the Flood Control Commission. In the dike area, the Glen Dean Limestone has been dissolved or eroded away and replaced by gray and brown silty clay which is fairly firm and impervious. The dike will be founded on the silty clay after the organic material has been stripped off. Undistrubed samples will be drilled in the dike during the design exploration stage. The left abutment of the dike is composed of poorly cemented Mansfield Sandstone. All but the lower 6 feet of Glen Dean Limestone has been stripped off. According to the driller, the lower 19 feet of the Mansfield Sandstone in BH-23 was rotten, soft with loose sand and quick in the lower portion. In the dike area, the Glen Dean Limestone is full of solution channels. It is believed that a triple grout curtain will effectively seal this interval.

28. DAM.

The dam will primarily be constructed of rock excavated from the spillway and soil from the left abutment borrow area in addition to miscellaneous materials required for the drain and graded aggregate zones. Top of dam width will be 30 feet at elevation 565. The downstream slope will be a constant 1 on 3. Upstream slopes will be as follows:

Elev. 565 to Elev. 550	1 on 2.5
Below Elev. 550	1 on 3.5

The upstream slope will be protected against wave action by an 18-inch thickness of riprap on 9 inches of bedding above elevation 501. Downstream slope protection would be provided by placing selected limestone in downstream face of the rock fill section. A blanket or transition zone will be provided between the impervious material and rock fill by a 5-foot horizontal width of filter graded drain material and a

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graded aggregate zone also 5 feet wide. A section is shown on plate E-24. It is planned to place the rock excavated from the spillway in 2 foot lifts within the dam and compact by 4 passes with a 50 ton rubber tire roller. Soil will be placed in 8 inch lifts and compacted to at least 95 percent Standard Density.

29. DIKE.

The dike will be constructed of soil obtained from the borrow area located between the dam and the dike. The top width will be 30 feet at elevation 565, side slopes are 1 on 3. The upsteam slope will be protected with 18 inches of riprap over 9 inches of bedding. A sloping and horizontal drain will be utilized for internal water control. Top of the drain will be at elevation 550 and will be placed on a slope of 1 vertical on 1.5 horizontal. The sloping drain will discharge into a horizontal drain 2 feet thick which will exit seepage at the downstream toe of the dike. The downstream slope will be protected by turf. Compaction will be to at least 95% Standard Density. This will be accomplished by placement of soil in 8 inch lifts with compaction by at least 6 passes with a tamping roller.

30. GROUND WATER AND RESERVOIR TIGHTNESS.

a. Right abutment and right bank drainage divide. Static water has been plotted on the geologic profile prepared by the Flood Control Commission. The water table has high and low peaks but the effective water table is elevation 500± from the right abutment to BH-9. The north-south ravines in the NW 1/4 Sec. 1 and the W 1/2 Sec. 12 represent one of the dominant joint directions. Purdue Forage Farm wells 1, 2, and 5 and BH-9 which are located in the alignment of these two ravines have low static water elevations, 500± thus indicating solution through the Golconda Limestone along the N-S joint. Northeast of the N-S ravine the water table rises rapidly and is well above the top of dam. Thus, from the right abutment to the above mentioned N-S ravines, there will be considerable leakage when the pool is above elevation 500. The leakage would be in the form of springs in George Creek and possible springs or seeps downstream from the dam.

b. Left abutment of the dam and dike area. The Glen Dean Limestone in the left abutment and dike area has numerous solution joints and cavities. Ground water under the left aubtment stands at elevation 490, in the Golconda Limestone. Somewhere between BH-17 and BH-20 static water raises to elevation 531. The Flood Control Commission does not have any water readings on BH-18 and BH-19A. The water table is elevation 522 beneath the dike and 510 in BH-24 some 600 feet into the hill from the left abutment of the dike. Thus, based on the present information, there is not a positive high water table in the left abutment of the dike to grout to.

31. GROUTING.

No grouting will be required in the valley. In estimating the amount of grouting necessary, the estimate has been broken into two categories: grouting to protect the structures and grouting to hold a pool. The degree of solution at the Patoka site is similar to that at Nolin Reservoir where the Glen Dean, Hardinsburg and Golconda Formations form the abutments. A triple grout curtain was used effectively at Nolin. The outer lines use a sand-cement mix. After these lines are grouted the centerline of neat grout is used. It is proposed to use a triple grout curtain from the dike to the spillway and a single curtain into the drainage divides.

a. Triple grout curtain to protect the structures. The following assumptions have been made in estimating the cost of grouting: The top of the curtain would be elevation 565, top of dam. The base of the curtain would be in the shales beneath the Golconda Limestone with the exception of the dike area which can be stepped up into the Hardinsburg Formation. Grout consumption is assumed at 3 sacks of cement per linear foot of drilling in the grout zone with an average spacing of 10 feet between grout holes. It is estimated that grout can be placed at $2.50 per sack and the cost of EX drilling at $2.00 per foot. Estimated cost of drilling and grouting to protect the structures is $2,000,000.00.

b. The same assumptions were made for the single line curtain into the drainage divides to insure a pool. Estimated cost of grouting is $500,000.00.

32. SOURCES OF CONSTRUCTION MATERIALS.

a. General. Table 3 below shows the origin and distribution of all major construction materials. Rock will be excavated from the spillway which will be utilized as follows:

Random rock fill zones of the dam.

Soil for construction of the dam and dike will be obtained from the borrow area located on the hilltop between the dam and dike. Approximately 750,000 cubic yards of borrow are available here. Materials required for construction of the drains, bedding layers and graded aggregate zones will be obtained commercially.

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AD-A036 533   ARMY ENGINEER DISTRICT LOUISVILLE KY   F/G 8/6
WABASH RIVER BASIN COMPREHENSIVE STUDY COVERING RESERVOIR SITES--ETC(U)
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3 OF 7
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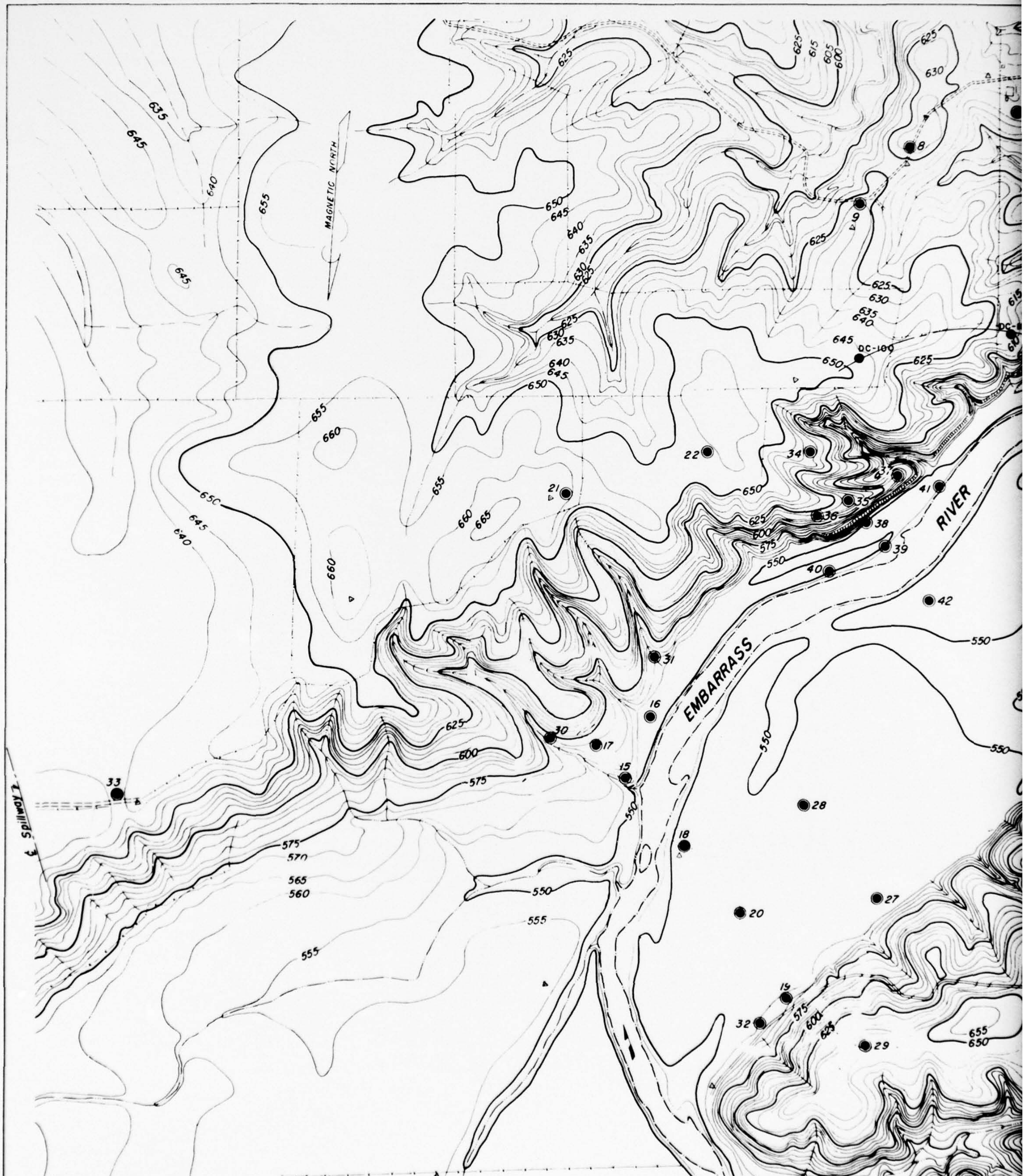
TABLE 3

PATOKA RESERVOIR

ORIGIN AND DISPOSITION OF CONSTRUCTION MATERIALS

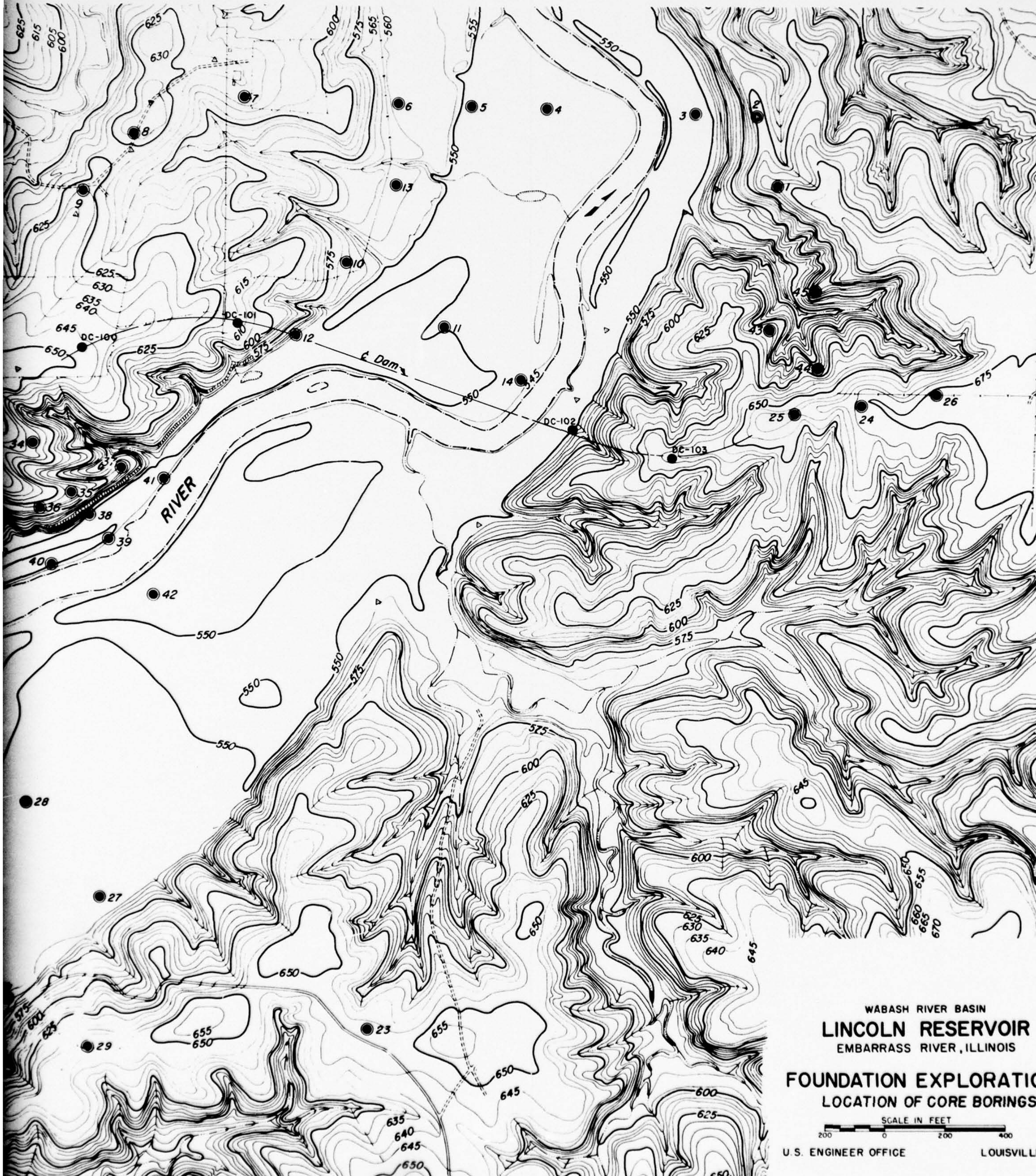
Feature	Sub-Feature	Quantity Cu. Yds.	Origin & Disposition
Spillway	Excavation, Soil	417,800	Place suitable in dam. Use all other in blanket.
	Excavation, Rock	436,000x1.20= 523,000	Place in dam.
Conduit & Channels	Excavation, Soil	20,400	Place suitable in dam. Use all other in blanket.
	Excavation, Rock	950	Place in dam.
Dam	Stripping and Trenching	110,300	Use suitable in dam. All other in blankets.
	Borrow	348,000	Obtain from borrow areas and required const.
	Riprap	18,800	Obtain commercially.
	Graded Aggregate	18,475	Obtain commercially manufactured material.
	Drain Material	18,475	Obtain commercially manufactured material.
	Bedding	9,200	Obtain commercially natural or manufactured material.
Dike	Stripping and Trenching	14,400	Place suitable in dike - Place all other in upstream blanket-dam.
	Borrow	161,000	Obtain from borrow areas and req'd const.
	Riprap	6,200	Obtain commercially.
	Bedding	3,100	Obtain commercially natural or manufactured material.

b. Concrete aggregate. There is a possibility that fine aggregate can be obtained near the construction area from the valley alluvial sand or sand terraces. The closest source of coarse aggregate is a limestone quarry near Eckerty, Indiana, a haul of approximately 10 miles. There is an abandoned quarry in the left abutment approximately 1/2 mile downstream from the proposed centerline. The producing interval was the Glen Dean Limestone.



MAGNETIC NORTH
EMBARRASS
RIVER
DC-109
Spillway

CORPS OF ENGINEERS, U.S. ARMY



WABASH RIVER BASIN

LINCOLN RESERVOIR

EMBARRASS RIVER, ILLINOIS

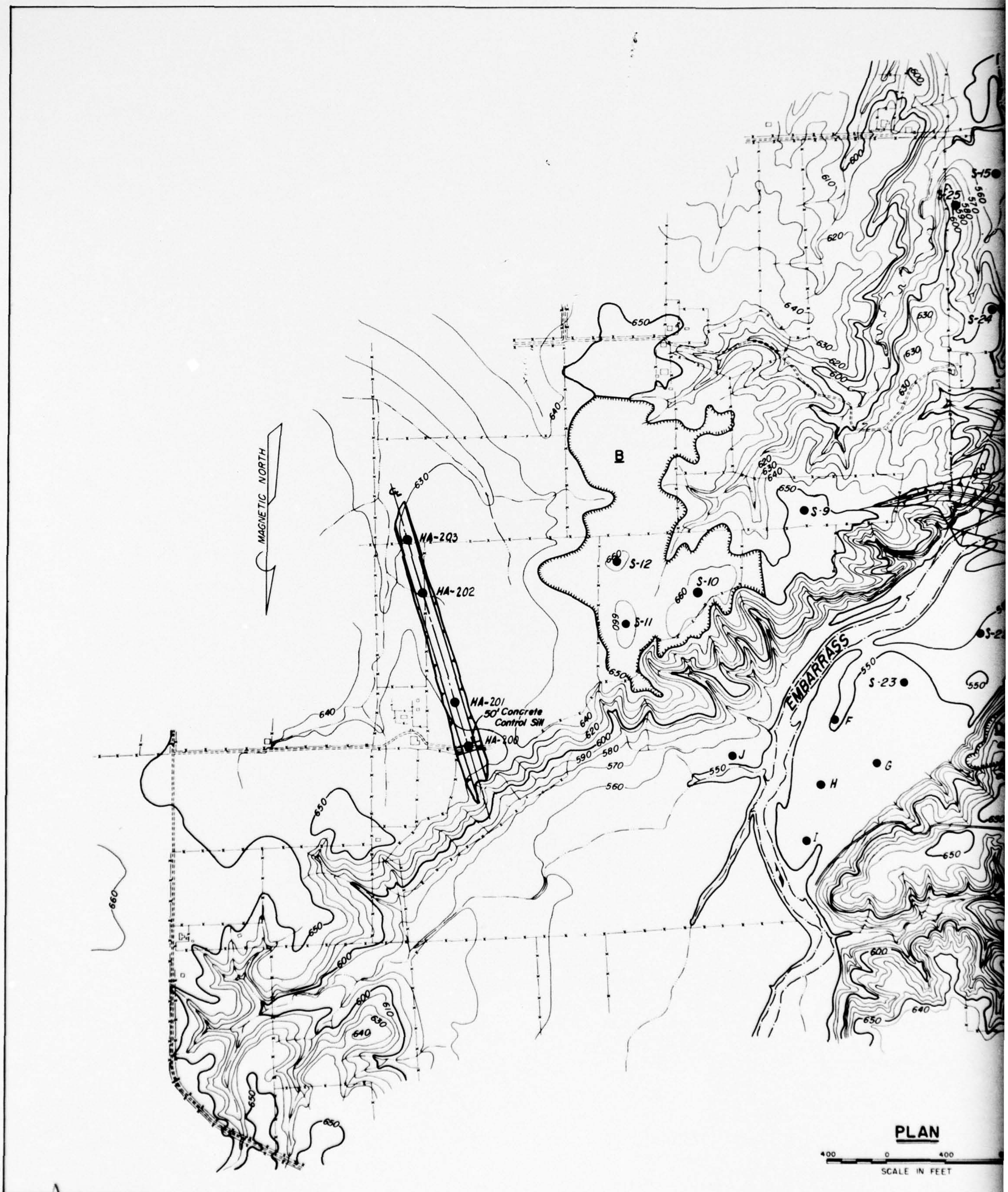
FOUNDATION EXPLORATIONS

LOCATION OF CORE BORINGS

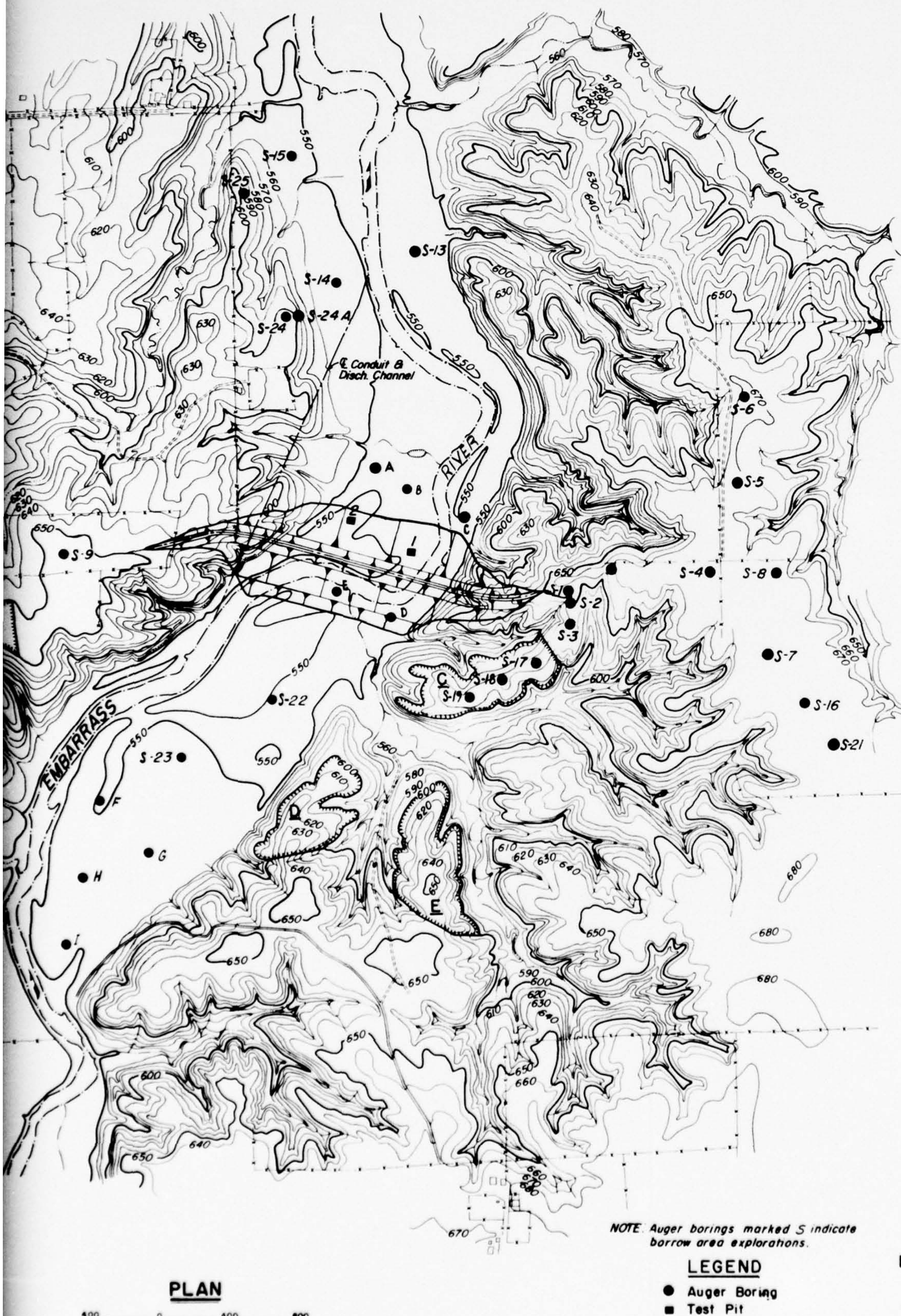
SCALE IN FEET

200 0 200 400

U.S. ENGINEER OFFICE LOUISVILLE, KY.



MAGNETIC NORTH
B
HA-203
HA-202
HA-201
50' Concrete Control Sill
HA-200
S-9
S-10
S-11
S-12
S-15
S-24
S-23
J
F
G
H
I
EMBARRASS
650
640
630
620
610
600
590
580
570
560
550
660
PLAN
400
0
400
SCALE IN FEET



NOTE: Auger borings marked S indicate borrow area explorations.

LEGEND

- ● Auger Boring
- ■ Test Pit
- Borrow Area Limits

WABASH RIVER BASIN

LINCOLN RESERVOIR

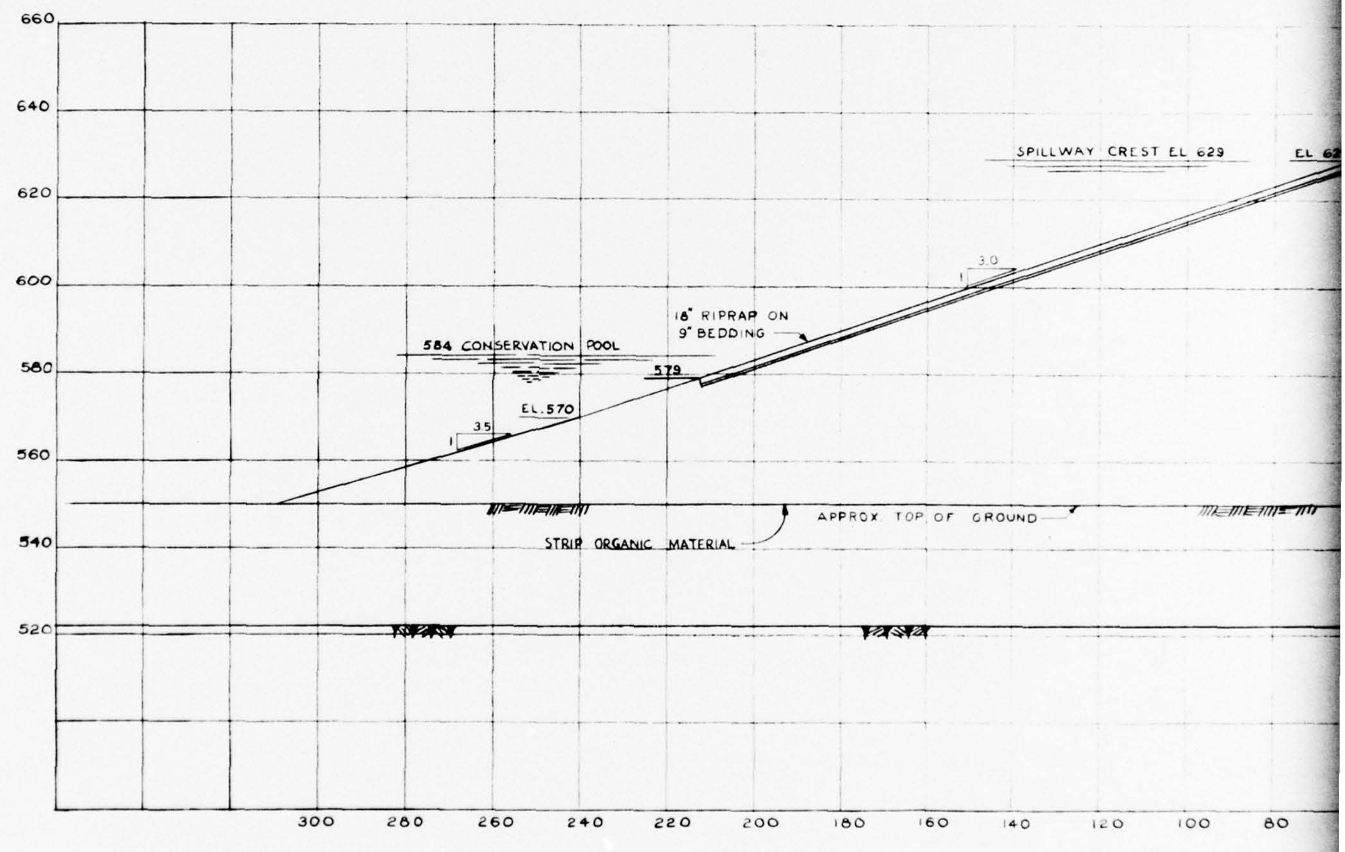
EMBARRASS RIVER, ILLINOIS

FOUNDATION EXPLORATIONS

LOCATION OF AUGER BORINGS - TEST PITS

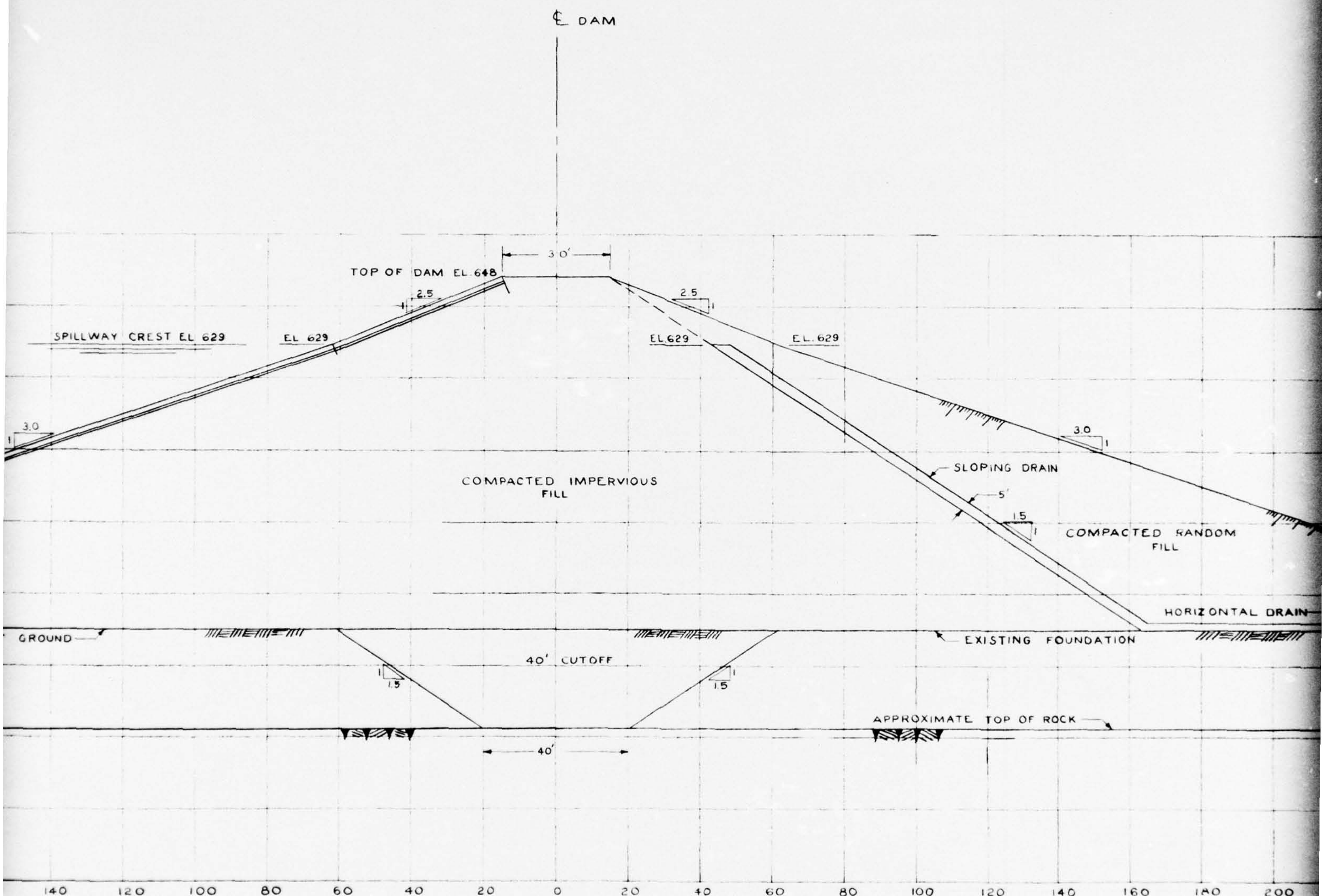
SCALE AS SHOWN

U.S. ENGINEER OFFICE, LOUISVILLE, KY.



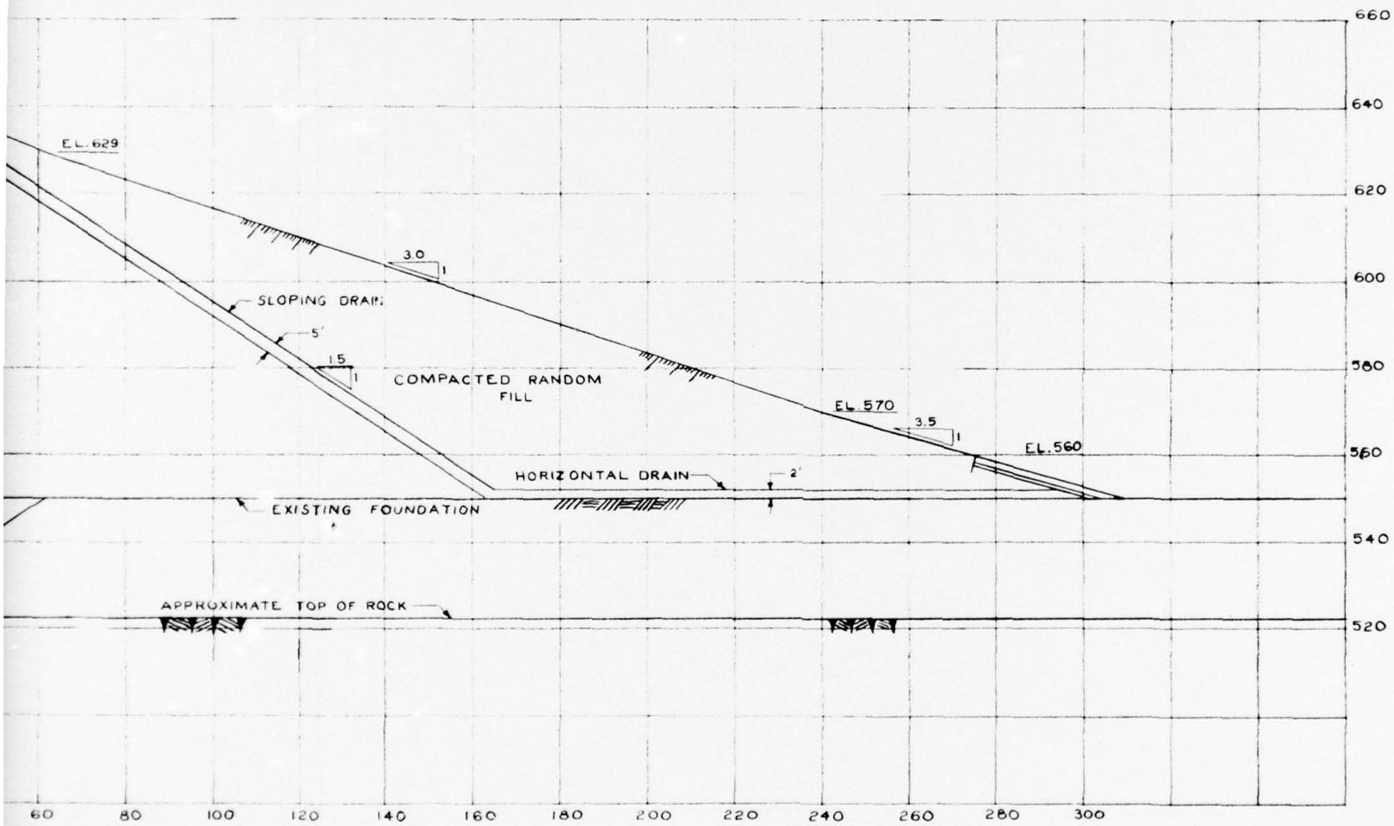
660
640
620
600
580
560
540
520
SPILLWAY CREST EL 629
EL 62
3.0
1
18" RIPRAP ON
9" BEDDING
584 CONSERVATION POOL
579
EL.570
3.5
1
APPROX. TOP OF GROUND
STRIP ORGANIC MATERIAL
300
280
260
240
220
200
180
160
140
120
100
80

2



TYPICAL SECTION

3



WABASH RIVER BASIN

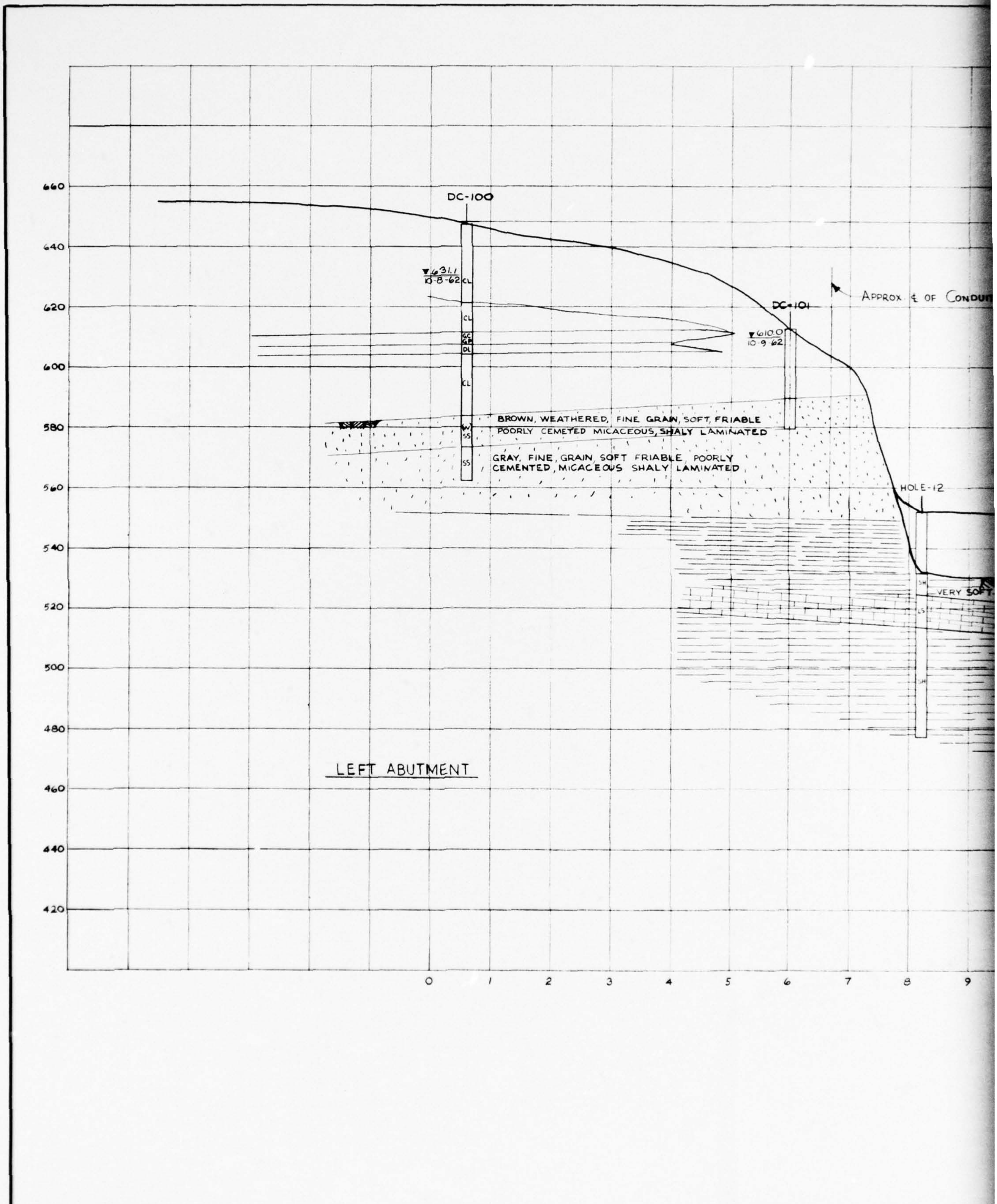
LINCOLN RESERVOIR

EMBARRASS RIVER, ILLINOIS

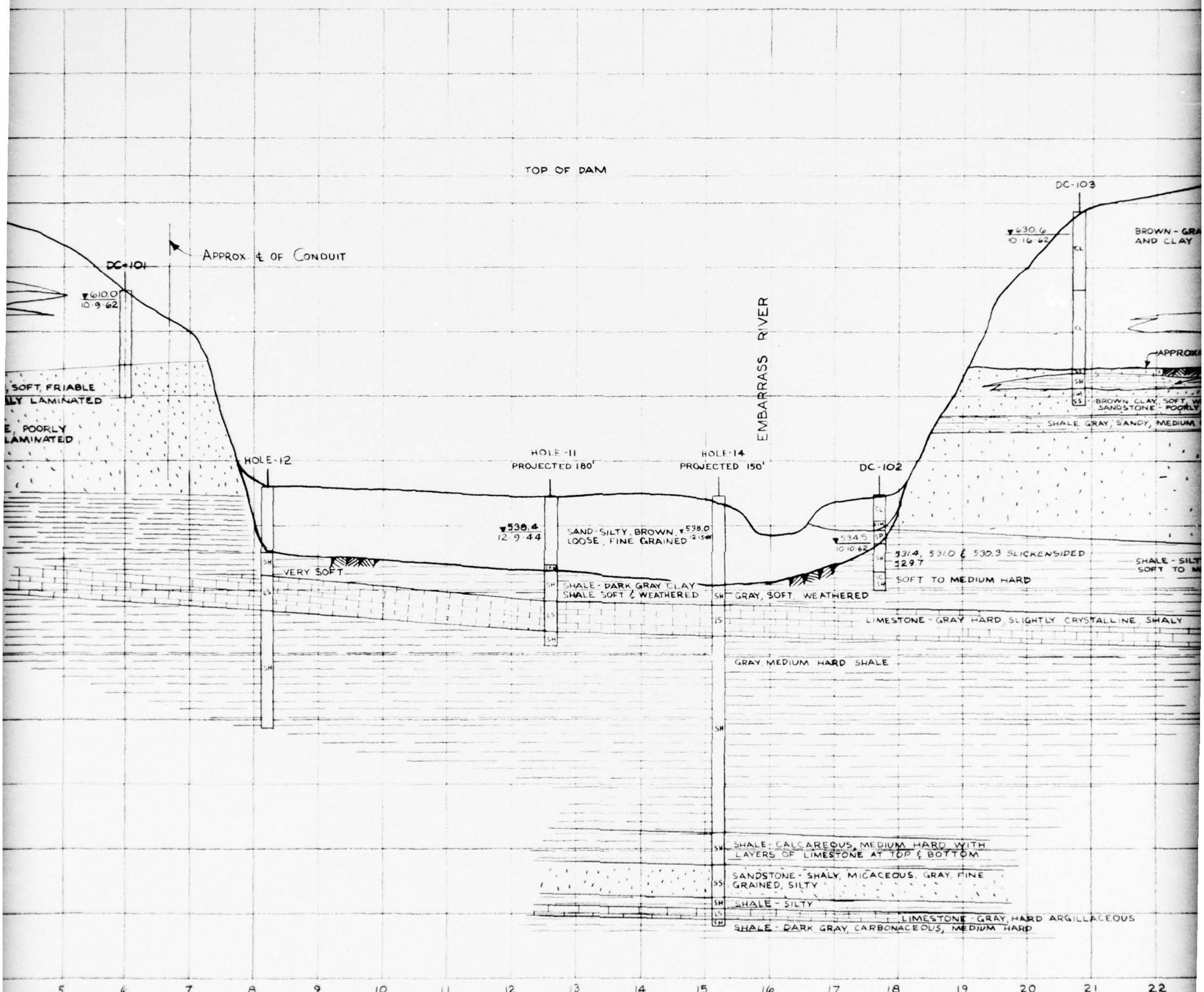
SECTION OF DAM

DR. BY L.A.T. TR. BY B.G.R.

PLATE E-3



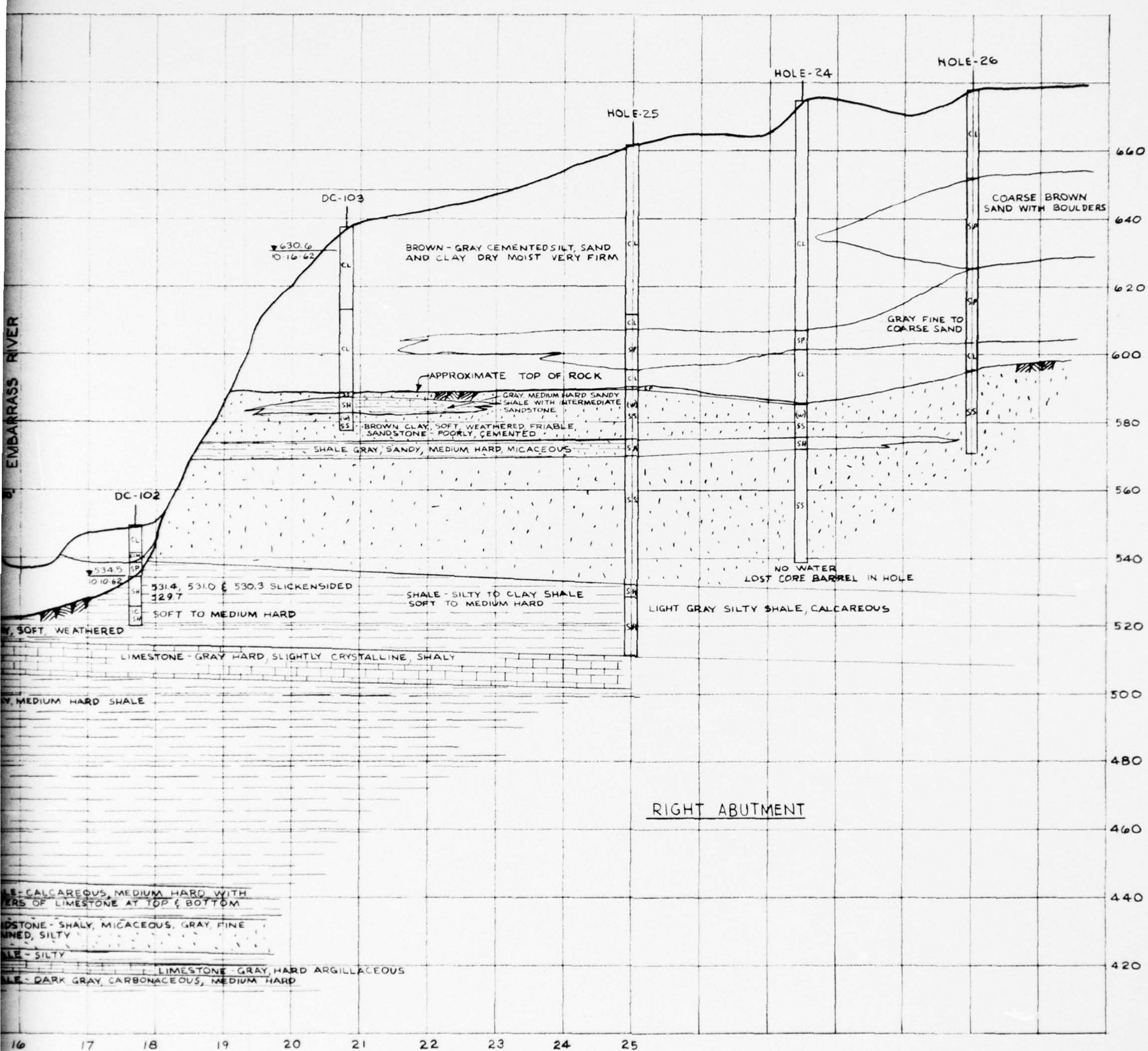
660
640
620
600
580
560
540
520
500
480
460
440
420
DC-100
▼631.1
10-8-62
CL
CL
DL
CL
W
SS
SS
DC-101
▼610.0
10-9-62
APPROX. ℄ OF CONDUIT
BROWN, WEATHERED, FINE GRAIN, SOFT, FRIABLE
POORLY CEMETED MICACEOUS, SHALY LAMINATED
GRAY, FINE, GRAIN, SOFT FRIABLE, POORLY
CEMENTED, MICACEOUS SHALY LAMINATED
HOLE-12
SH
LS
SH
VERY SOFT
LEFT ABUTMENT
0
1
2
3
4
5
6
7
8
9



PROFILE

SCALE:
HORIZONTAL 1" = 100'-0"
VERTICAL 1" = 20'-0"

3



WABASH RIVER BASIN

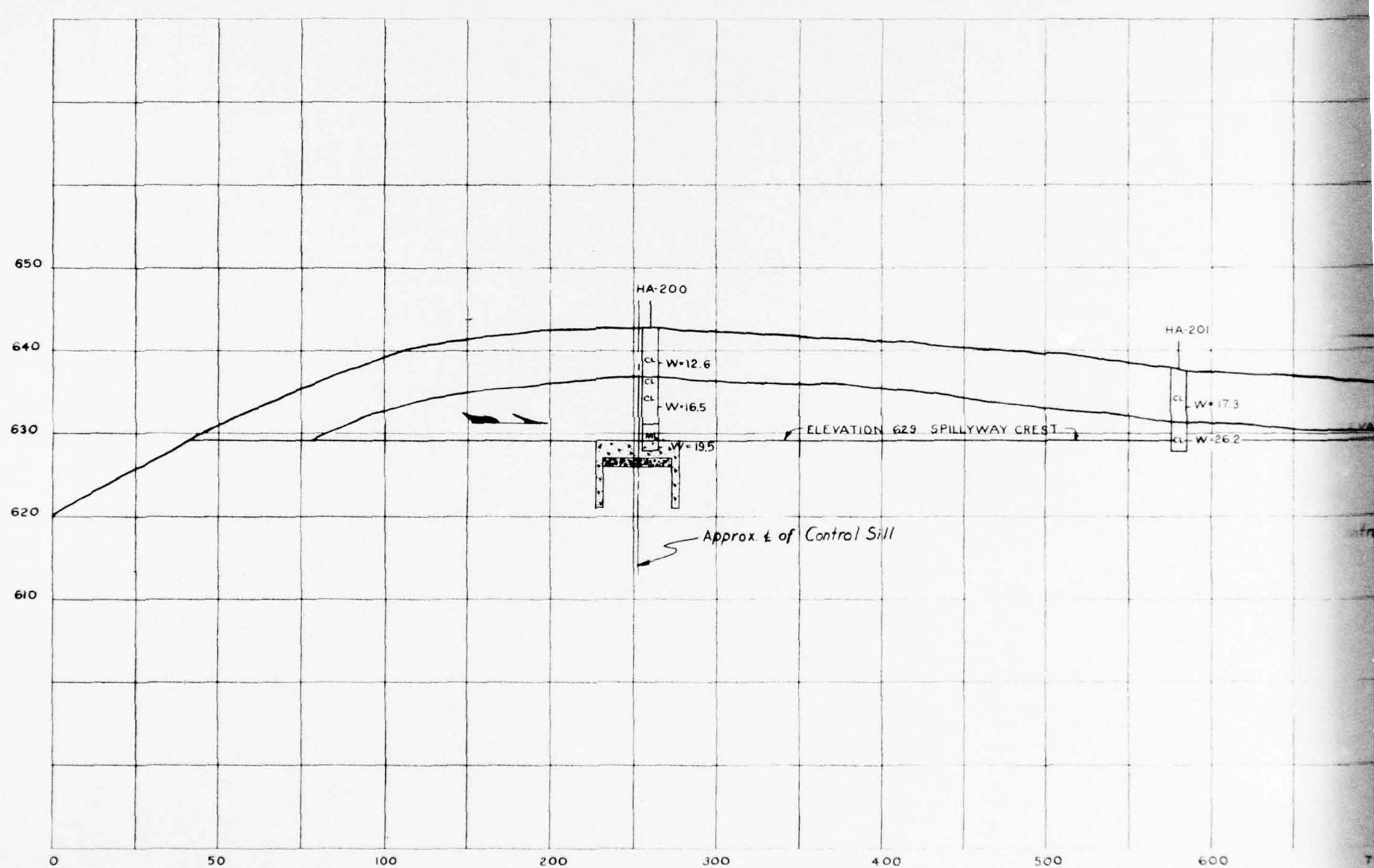
LINCOLN RESERVOIR, ILL.

EMBARASS RIVER

GEOLOGIC PROFILE - DAM

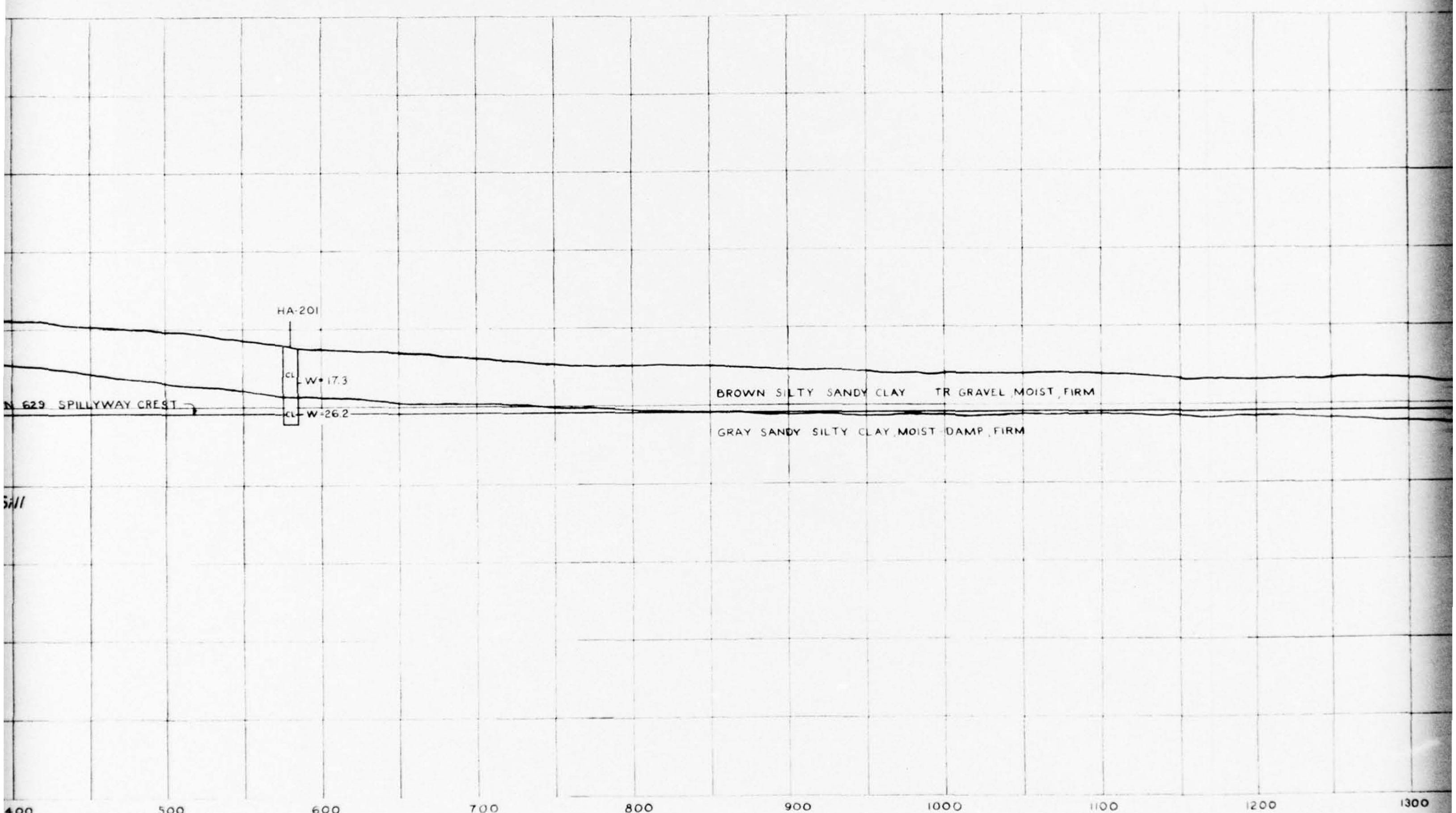
DESIGNED BY: H.E.T. TRACED BY: K.E.S.

PLATE E-4



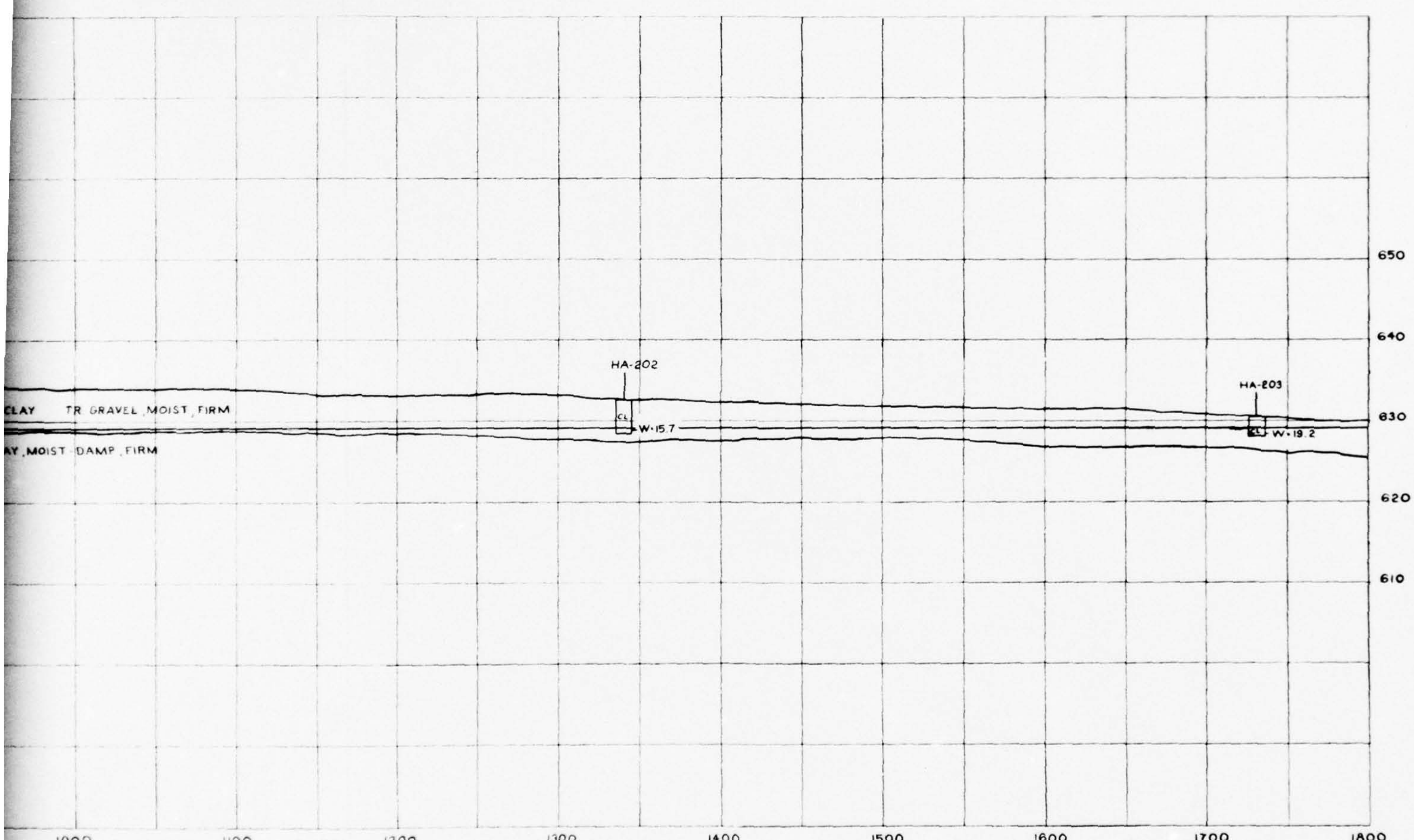
650
640
630
620
610
HA-200
CL
W=12.6
CL
CL
W=16.5
W=19.5
ELEVATION 629 SPILLWAY CREST
HA-201
CL
W=17.3
CL
W=26.2
Approx. ℄ of Control Sill
0
50
100
200
300
400
500
600

2



HA-201
CL
W=17.3
CL
W=26.2
629 SPILLWAY CREST
BROWN SILTY SANDY CLAY TR GRAVEL MOIST, FIRM
GRAY SANDY SILTY CLAY MOIST-DAMP, FIRM
400
500
600
700
800
900
1000
1100
1200
1300

3



WABASH RIVER BASIN

LINCOLN RESERVOIR

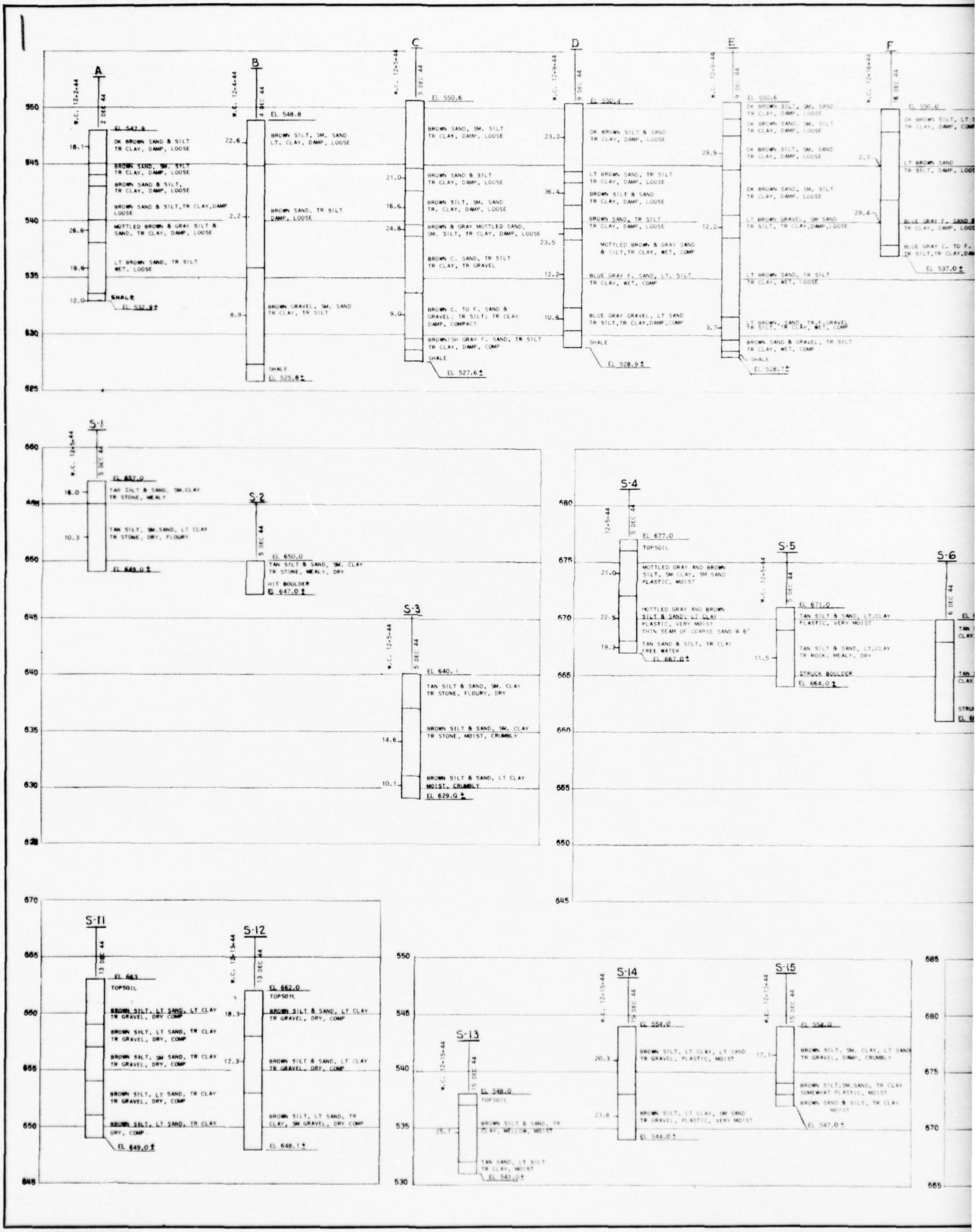
EMBARRASS RIVER, ILLINOIS

GEOLOGIC PROFILE - SPILLWAY

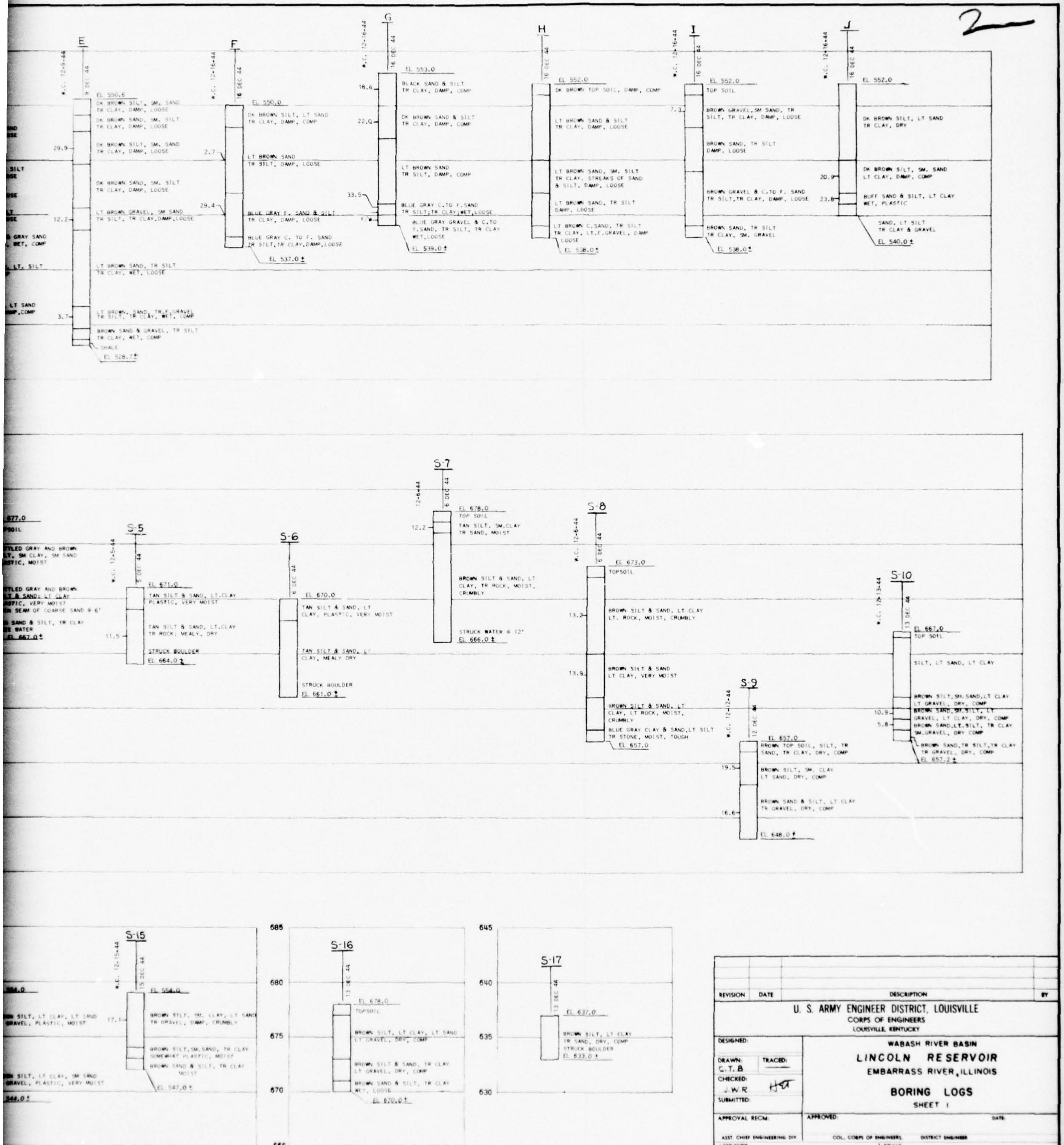
DR. BY H.E.T. TR. BY B.G.R.

PLATE E-5

CORPS OF ENGINEERS



U. S. ARMY



REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

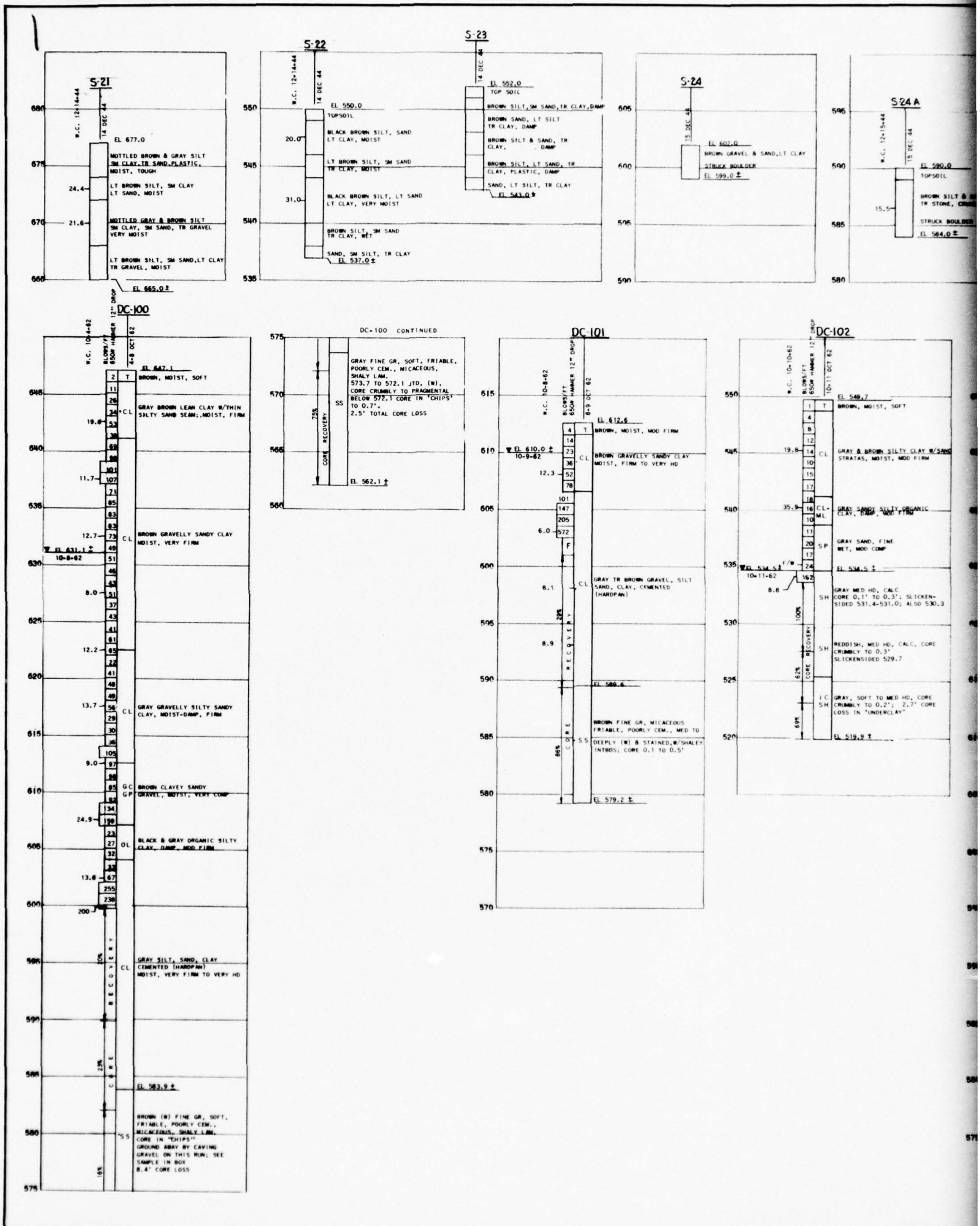
WABASH RIVER BASIN
LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS

BORING LOGS
SHEET 1

DESIGNED:
DRAWN: C.T.B TRACED:
CHECKED: J.W.R
SUBMITTED:
APPROVAL RECM: APPROVED: DATE:
ASST. CHIEF ENGINEERING DIV. COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
APPROVED: SCALE:
CHIEF, ENGINEERING DIVISION DRAWING NUMBER

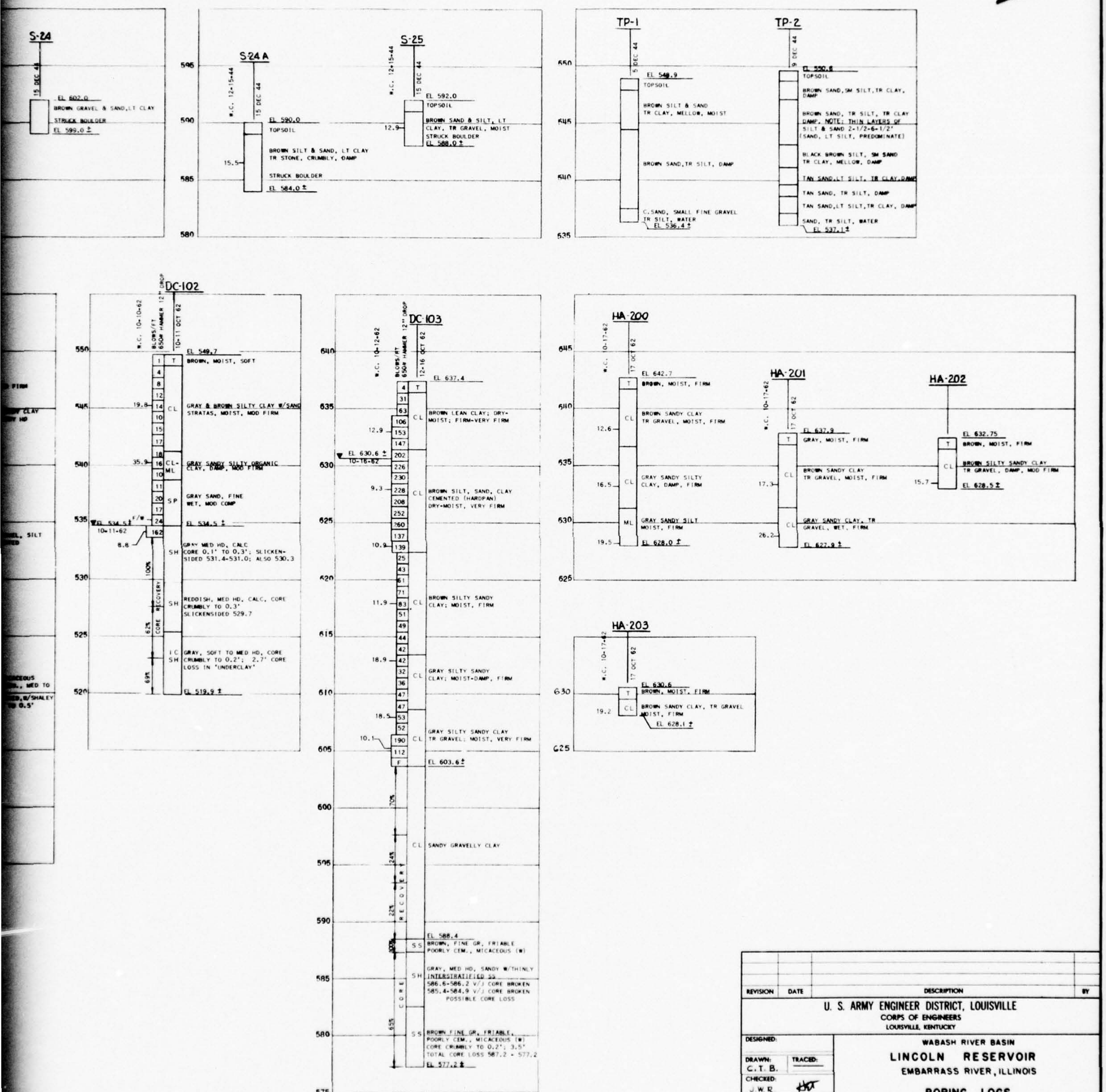
PLATE E-8

CORPS OF ENGINEERS



U. S. ARMY

2



REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

DESIGNED:
DRAWN: C. T. B. TRACED:
CHECKED: J. W. R.
SUBMITTED:

WABASH RIVER BASIN
LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS
BORING LOGS
SHEET 2

APPROVAL RECM: APPROVED: DATE:
ASST. CHIEF ENGINEERING DIV. COL. CORPS OF ENGINEERS DISTRICT ENGINEER
APPROVED: SCALE:
DRAWING NUMBER
CHIEF, ENGINEERING DIVISION

WAR DEPARTMENT

HOLE NO. 1

SURFACE ELEVATION 639.9

0–25	TILL, clay, sand and gravel in varying proportions, brown, compact, medium hard.	Wisconsin
25–51	TILL, clay, sand and gravel in varying proportions, gumbo, bluish grey, compact, hard.	
	CLAY, stiff, dark brown, little silt and sand.	
	SAND, medium hard, fine, brown, little clay.	
	CLAY, stiff, light to dark brown.	
	SHALE, silty, grey, very soft, highly weathered.	
	SHALE, soft, black, silty, carbonaceous, very soft.	
	TOP OF ROCK ELEV. 566.6	
	SHALE, sandy, medium hard.	
	SHALE, soft, grey clay.	
	SANDSTONE, with silty shale interbedding, medium hard, brown, grey shale.	Newton cyclothem of post-Alleghenian of the Pennsylvanian system.
	COAL, shaly.	
	SHALE, grey, soft to medium hard, with thin layers of argillaceous limestone.	
	LIMESTONE, hard, grey.	
	BOTTOM OF HOLE ELEV. 505.5	

DEPTH OF HOLE 134.4'
DEPTH OF OVERBURDEN 73.3'
FEET CORED 61.1'
PERCENT CORE RECOVERY 72.5

HOLE NO. 2

SURFACE ELEVATION 627.3

TILL, compact mixture of clay, sand and gravel in varying amounts, hard, bluish to grey.	Wisconsin
TILL, compact mixture of clay, sand and gravel in varying amounts, hard, weathering to a brownish yellow near the bedrock.	
TOP OF ROCK ELEV. 580.0	
SANDSTONE, soft, weathered, grey to yellow.	Newton cyclothem, Post-Alleghenian of Pennsylvanian system.
CREVICES, four openings totalling 2.7 feet, all material lost.	
LIMESTONE, hard, sandy.	
SANDSTONE, grey, shattered.	
LIMESTONE	
SHALE, hard, black to grey, calcareous.	
SHALE, grey to reddish brown, hard to medium hard.	
BOTTOM OF HOLE ELEV. 516.5	

DEPTH OF HOLE 110.8'
DEPTH OF OVERBURDEN 47.3'
FEET CORED 63.5'
PERCENT CORE RECOVERY 50.2

SURFACE

2

Wisconsin

Newton cyclothem, Post-Allegheninan of Pennsylvanian system.

HOLE NO. 3

SURFACE ELEVATION 548.4

SILT, clayey, dark brown.

SAND, some silt and clay, brown, water bearing.

TOP OF ROCK ELEV. 532.1

SHALE, soft, grey, calcareous hackley fracture.

SHALE, soft, greenish grey, slip fracture, calcareous.

SHALE, siltstone, non-calcareous with limestone nodules.

LIMESTONE, argillaceous, shale partings, medium soft.

SHALE, greenish to dark grey, silty, calcareous, fossilized.

SHALE, non-calcareous, grey, medium hard.

Alluvium

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

BOTTOM OF HOLE ELEV.	477.8
DEPTH OF HOLE	70.6'
DEPTH OF OVERBURDEN	16.3'
FEET CORED	54.3'
PERCENT CORE RECOVERY	82.9

HOLE NO. 4

SURFACE ELEVATION 548.4

LOAM, soft, silty, clayey.

SAND, coarse, brown at top and bottom, grey between, with small to medium gravel, some silt at bottom.

SHALE, grey, clay, weathered.

LIMESTONE, dark grey weathered, soft.

TOP OF ROCK ELEV. 521.2

SHALE, brown to grey clay, weathered, soft.

LIMESTONE, blue to grey, hard, slightly weathered, clay seams, top 1' soft.

SHALE, hard, sound, grey, clay.

SHALE, hard, sound, black, clay, carbonaceous.

Alluvium

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

BOTTOM OF HOLE ELEV.	461.9
DEPTH OF HOLE	86.5'
DEPTH OF OVERBURDEN	27.2'
FEET CORED	59.3'
PERCENT CORE RECOVERY	85.0

WABASH RIVER BASIN

LINCOLN RESERVOIR

EMBARRASS RIVER, ILLINOIS

FOUNDATION EXPLORATIONS

CORE BORING LOGS

SHEET 1 OF 9 SHEETS

U.S. ENGINEER OFFICE, LOUISVILLE, KY.

HOLE NO. 5

SURFACE ELEVATION 547.3

SILT, clayey, soft, damp, brown, grading into sand at 10.0'.	Alluvium
SHALE, very soft, blue, sandy at top.	Classed as Overburden
SHALE, silty, blue, calcareous, limestone nodules, soft, highly weathered.	
TOP OF ROCK ELEV. 515.5	
LIMESTONE, gray, interbeds of soft shal'y hard, sound.	Newton cyclothem, Post-Alleghenian of Pennsylvanian system.
SHALE, silty, calcareous, medium hard, gray.	
SHALE, clay, hard, sound black, carbonaceous, non-calcareous, fossiliferous	
LIMESTONE, argillaceous, gray, hard.	
SHALE, silty, gray, cross-laminated.	
SHALE, black, sandy, medium hard.	
BOTTOM OF HOLE EL. 414.8	

DEPTH OF HOLE	132.5'
DEPTH OF OVERBURDEN	31.8'
FEET CORED	100.7'
PERCENT CORE RECOVERY	95.6

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150

HOLE NO. 6

SURFACE ELEVATION 558.6

CLAY, stiff, plastic, mottled brown & gray, silty.	
SAND, and gravel.	
TOP OF ROCK ELEV. 544.0	
SHALE, gray, clay, soft.	Newton cyclothem, Post-Alleghenian of Pennsylvanian system.
LIMESTONE, gray, shal'y, sound, hard.	
SHALE, sandy, soft, badly weathered.	
SHALE, gray and brown, interbedded with gray shal'y limestone, hard & fairly sound	
LIMESTONE, bluish gray, hard and sound.	
SHALE, gray clay, calcareous, hard and sound.	
SHALE, black clay, hard, sound, carbonaceous.	
BOTTOM OF HOLE ELEV. 488.1	

DEPTH OF HOLE	70.5'
DEPTH OF OVERBURDEN	14.6'
FEET CORED	55.9'
PERCENT CORE RECOVERY	90.8

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

2

Newton cyclothem, Post-Allegheniam of Pennsylvanian system.

HOLE NO. 7

SURFACE ELEVATION 619.0

SILTY LOAM, dark brown.	
SILT, clayey, hard, compact, grey.	
TILL, clay, sand, gravel, in varying proportions tightly compacted, hard, gray, loosely packed at bottom.	Wisconsin
SAND, coarse, silty in top 10', very fine, gray and brown, micaceous, (Highly weathered sandstone).	
TOP OF ROCK ELEV. 548.8	
SHALE, clay, gray, hard, sound, slightly weathered at top, carbonaceous between El. 542-538. mottled gray & brown from El. 532-522.	Newton cyclothem Post-Alleghenian of Pennsylvanian system.
LIMESTONE, shal'y, light bluish gray, medium hard to hard.	
SHALE, clay, hard, gray to black.	
BOTTOM OF HOLE ELEV. 499.0	
DEPTH OF HOLE 120.0'	
DEPTH OF OVERBURDEN 70.2'	
FEET CORED 49.8'	
PERCENT CORE RECOVERY 88.0	

HOLE NO. 8

SURFACE ELEVATION 632.5

TILL, clay, sand and gravel in varying proportions, compact, medium hard to hard, calcareous "gumbo."	
SAND, grayish, silty, coarse, probably lenticular deposit.	
TILL, clay, sand and gravel in varying proportions, compact, medium hard to hard, calcareous "gumbo."	Wisconsin
TOP OF ROCK ELEV. 562.9	
SANDSTONE, soft, tannish grey, coarse, micaceous.	
SHALE, gray to very dark gray, medium soft to hard, micaceous, fossiliferous, calcareous.	Newton cyclothem of the post-Alleghenian of the Pennsylvanian system.
SHALE, with limestone interbeds and nodules, gray, medium soft.	
SHALE, grey mottled, clayey to silty at bottom, non-calcareous.	
LIMESTONE, shal'y, gray.	
SHALE, gray, hard, silty, calcareous.	
BOTTOM OF HOLE ELEV. 507.5	
DEPTH OF HOLE 125.0'	
DEPTH OF OVERBURDEN 69.6'	
FEET CORED 55.4'	
PERCENT OF RECOVERY 85.2	

WABASH RIVER BASIN

LINCOLN RESERVOIR

EMBARRASS RIVER, ILLINOIS

FOUNDATION EXPLORATIONS

CORE BORING LOGS

SHEET 2 OF 9 SHEETS

U.S. ENGINEER OFFICE, LOUISVILLE, KY.

HOLE NO. 9

SURFACE ELEVATION 631.8

LOAM	
TILL, clay, sand and gravel in varying proportions, grey to bluish grey.	
CLAY, blue, medium soft.	
GRANITE, boulder.	Wisconsin
TILL, clay, sand and gravel in varying proportions, grey to bluish grey.	
TOP OF ROCK ELEV. 585.1	
SHALE, soft, grey.	
SANDSTONE, soft, greyish, micaceous.	
SHALE, hard, grey, clay, carbonaceous.	Newton cyclothem, Post-Alleghenian of Pennsylvanian system.
SHALE, soft, grey to black.	
BOTTOM OF HOLE ELEV. 531.8	
DEPTH OF HOLE 100.0'	
DEPTH OF OVERBURDEN 46.7'	
FEET CORED 53.3'	
PERCENT CORE RECOVERY 77.8	

HOLE NO. 13

SURFACE ELEVATION 562.5

TILL, silt, sandy with some small gravel.	Wisconsin
TOP OF ROCK EL. 542.5	
SHALE, clay, grey, med. soft to soft.	Newton cyclothem Post-Alleghenian of Pennsylvanian system.
LIMESTONE, grey, shaly, med. hard, broken, fossiliferous.	
SHALE, dark grey, med. hard.	
BOTTOM OF HOLE ELEV. 506.5	
DEPTH OF HOLE 56.0'	
DEPTH OF OVERBURDEN 20.0'	
FEET CORED 36.0'	
PERCENT CORE RECOVERY 85.0	

HOLE NO. 10

SURFACE ELEVATION 566.4

TILL, silty clay with small boulders, brown, compact.	Wisconsin
TOP OF ROCK ELEV. 551.0	
Water Table	
SHALE, clay, soft and weathered to elevation 549.0. med. hard, varying in color from grey to almost black, with some greyish brown.	
LIMESTONE, fresh water lime, medium soft, shaly, badly broken in core, grey, sound below El. 515.0.	
SHALE, silt, calcareous, grey, hard.	
SHALE, dark grey, hard, sound, carbonaceous, pyritic below El. 465.0.	Newton cyclothem Post-Alleghenian of Pennsylvanian system.
LIMESTONE, grey, hard, fossiliferous.	
SHALE, grey, hard, sound, calcareous, fossiliferous.	
SANDSTONE, grey, hard, fine grained, micaceous.	
SHALE, gray, hard, sandy.	
LIMESTONE, grey, shaly, hard, argillaceous.	
SHALE, clay, dark grey, med. soft, carbonaceous.	
BOTTOM OF HOLE ELEV. 420.2	
DEPTH OF HOLE 146.2'	
DEPTH OF OVERBURDEN 15.4'	
FEET CORED 130.8'	
PERCENT CORE RECOVERY 92.3	

SURFACE EL

SURFACE EL

2

Wisconsin

Newton cyclothem
ost-Alleghenian
f Pennsylvanian
ystem.

HOLE NO. 11

SURFACE ELEVATION 548.9

	SAND, silty, brown, loose, fine grained.	Alluvium
10	Water Table	
20	SAND AND GRAVEL, silty.	
	TOP OF ROCK ELEV. 526.5	
	SHALE, clay, dark grey, soft, weathered.	Newton cyclothem Post-Alleghenian of Pennsylvanian system.
30		
	LIMESTONE, shal'y, grey, broken above el. 513.4.	
40	SHALE, calcareous, silty, grey, med. hard.	
	BOTTOM OF HOLE ELEV. 502.7	
50		

DEPTH OF HOLE 46.2'
DEPTH OF OVERBURDEN 22.4'
FEET CORED 23.8'
PERCENT CORE RECOVERY 82.0

HOLE NO. 12

SURFACE ELEVATION 552.1

	ALLUVIUM, sand and silt, small gravel.	
10		
20	TOP OF ROCK ELEV. 531.9	
	SHALE	
30	LIMESTONE, grey, med. hard, shal badly broken.	
40	SHALE, silty, grey, med. hard, calcareous.	Newton cyclothem, Post-Alleghenian of Pennsylvanian system.
50	SHALE, clay, dark grey, med. hard.	
60		
70		
	BOTTOM OF HOLE ELEV. 477.1	
80		

DEPTH OF HOLE 75.0'
DEPTH OF OVERBURDEN 20.2'
FEET CORED 54.8'
PERCENT CORE RECOVERY 84.0

HOLE NO. 14

SURFACE ELEVATION 549.0

	SAND, silty with some gravel, loose.	Alluvium
10	Water Table	
20		
	SHALE, very soft.	
30	TOP OF ROCK ELEV. 520.2	
	SHALE, grey, soft, weathered.	
	LIMESTONE, grey, hard, slightly crystalline, pyritic and shal'y, broken below el. 514.3.	
40		
50		
	SHALE, grey, med. hard, sound.	
60		
70		Newton cyclothem Post-Alleghenian of Pennsylvanian system.
80		
90		
100		
	SHALE, calcareous, med. hard, with layers of limestone at top and bottom.	
110		
	SANDSTONE, shal'y, micaceous, grey, fine grained, silty.	
120		
	SHALE, silty.	
130	LIMESTONE, grey, hard, argillaceous.	
	SHALE, dark grey, carbonaceous, med. hard.	
	BOTTOM OF HOLE ELEV. 415.9	
140		

DEPTH OF HOLE 133.1'
DEPTH OF OVERBURDEN 28.8'
FEET CORED 104.3'
PERCENT CORE RECOVERY 96.0

WABASH RIVER BASIN

LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS

FOUNDATION EXPLORATIONS

CORE BORING LOGS

SHEET 3 OF 9 SHEETS

U.S. ENGINEER OFFICE, LOUISVILLE, KY.

HOLE NO. 15

SURFACE ELEVATION 559.0

<u>ALLUVIUM</u>, silt with some sand and small gravel.

Water table

TOP OF ROCK ELEV. 534.6

<u>SHALE</u>

<u>LIMESTONE</u>, grey, hard, broken above El. 531.5 sound below El. 531.5

<u>SHALE</u>, silt, light grey, sound, med. hard.

<u>SHALE</u>, clay, dark grey, med. hard.

<u>LIMESTONE</u>

<u>SHALE</u>, silt, light grey, med. hard, calcareous.

<u>SHALE</u>, lime, calcareous, hard, grey.

<u>SANDSTONE</u>, shal'y, fine grained, grey.

<u>SHALE</u>, lime, med. hard, grey.

<u>SHALE</u>, clay, med. hard, gray.

BOTTOM OF HOLE ELEV. 438.5

DEPTH OF HOLE	120.5'
DEPTH OF OVERBURDEN	24.4'
FEET CORED	96.1'
PERCENT CORE RECOVERY	96.0

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

HOLE NO. 16

SURFACE ELEVATION 552.2

<u>OVERBURDEN</u>, alluvium and talus, silt, sand and small gravel, clayey. (0.5' of soft shale covering limestone.)

Water table

TOP OF ROCK ELEV. 533.3

<u>LIMESTONE</u>, grey, hard, broken above El. 530.5

<u>SHALE</u>, silty, grey, med. hard, calcareous.

<u>SHALE</u>, clay, dark grey, med. hard, sound.

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

BOTTOM OF HOLE ELEV. 491.9

DEPTH OF HOLE	60.3'
DEPTH OF OVERBURDEN	18.9'
FEET CORED	41.4'
PERCENT CORE RECOVERY	90.0'

HOLE NO. 17

SURFACE ELEVATION 567.0

<u>OVERBURDEN</u>, glacial till, talus.

Water table

TOP OF ROCK EL. 541.7

<u>SHALE</u>, silty, very soft, grey.

<u>LIMESTONE</u>, grey, argillaceous, very badly broken above El. 534.0

<u>SHALE</u>, clayey, grey, med. hard, calcareous

BOTTOM OF HOLE ELEV. 525.8

DEPTH OF HOLE	41.2'
DEPTH OF OVERBURDEN	25.3'
FEET CORED	15.9'
PERCENT CORE RECOVERY	65.0

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

SURFACE ELEVATIO

<u>TILL</u>, gla small g consolid

Water ta

<u>TILL</u>, gla dry, cl small

TOP OF

<u>SHALE</u>, c

<u>SHALE</u>,

<u>LIMESTO</u> med. ha

<u>SHALE</u>, calcare

BOTTOM

DEPTH O

DEPTH O

FEET CO

PERCENT

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

HOLE NO. 22

SURFACE ELEVATION 650.0

0–20	TILL, glacial, mostly sand and small gravel, silty, soft, unconsolidated.	Wisconsin
20	Water table	
20–78	TILL, glacial, compact, hard, dry, clay with sand and small gravel, gray.	Wisconsin
78	TOP OF ROCK ELEV. 573.0	
78–100	SHALE, clay, weathered, grey.	Newton cyclothem, Post-Alleghenian of Pennsylvanian system.
100–126	SHALE, silty, grey, hard, pyritic.	
126–130	LIMESTONE, grey, argillaceous, med. hard.	
130–163.7	SHALE, grey, med. hard, sound, calcareous, micaceous.	

BOTTOM OF HOLE ELEV. 486.3
DEPTH OF HOLE 163.7'
DEPTH OF OVERBURDEN 77.0'
FEET CORED 86.7'
PERCENT CORE RECOVERY 90+

HOLE NO. 21

SURFACE ELEVATION 661.0

0–10	TILL, glacial, compact.	Wisconsin
10–20	SAND, coarse, silty, compact.	
20–30	SAND, fine grained, silty, grey.	
30–86.5	GLACIAL TILL, grey, compact, occasional lenses of sand, and small gravel.	
53	Water table	
86.5	TOP OF ROCK ELEV. 574.5	
86.5–113	SHALE, clay, dark grey, med. hard to hard and sound below El. 569.5.	Newton cyclothem, Post-Alleghenian of Pennsylvanian system.
113–125	SHALE, silty, grey, med. hard, calcareous.	
125–129	SHALE, calcareous, bluish grey, soft.	
129–130	LIMESTONE, hard, grey.	
130–131.4	SHALE, calcareous, grey, soft.	

BOTTOM OF HOLE ELEV. 529.6
DEPTH OF HOLE 131.4'
DEPTH OF OVERBURDEN 86.5'
FEET CORED 44.9'
PERCENT CORE RECOVERY 80.0

WABASH RIVER BASIN

LINCOLN RESERVOIR

EMBARRASS RIVER, ILLINOIS

FOUNDATION EXPLORATIONS

CORE BORING LOGS

SHEET 4 OF 9 SHEETS

U.S. ENGINEER OFFICE, LOUISVILLE, KY.

WAR DEPARTMENT

HOLE NO. 23

SURFACE ELEVATION 646.±

TILL, glacial, clay, silt, sand, gravel, boulders, etc., in varying proportions, grey, hard. — Wisconsin

Water table

TOP OF ROCK ELEV. 554.9

SHALE, clay, soft, grey.

SHALE, silty, calcareous, some phosphate nodules. — Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

LIMESTONE, grey, hard, argillaceous.

SHALE

BOTTOM OF HOLE ELEV. 507.5

DEPTH OF HOLE	138.5'
DEPTH OF OVERBURDEN	91.1'
FEET CORED	47.4'
PERCENT CORE RECOVERY	85

HOLE NO. 24

SURFACE ELEVATION 674.4

TILL, glacial, clay, silt, sand, gravel, boulders, etc., in varying proportions, grey, hard. — Wisconsin

SAND

TILL, glacial.

TOP OF ROCK ELEV. 585.7

SANDSTONE, med. soft, grey, medium to fine grained, micaceous.

SHALE, grey, sandy, medium hard, micaceous.

Water table

SANDSTONE, grey, medium to fine grained, medium hard, micaceous. — Newton cyclothem Post-Alleghenian of Pennsylvanian system.

BOTTOM OF HOLE ELEV. 538.7

DEPTH OF HOLE	135.7'
DEPTH OF OVERBURDEN	88.7'
FEET CORED	47.0'
PERCENT CORE RECOVERY	87

SURFACE ELE

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Wisconsin

Newton cyclothem Post-Allegheinian of Pennsylvanian ystem.

CORPS OF ENGINEERS, U.S. ARMY

2

HOLE NO. 25

SURFACE ELEVATION 661.5

0–55	TILL, glacial, clay, silt, sand, gravel, boulders, etc., in varying proportions, grey, hard.	Wisconsin
55–67	SAND	
67–72	TILL, glacial.	
72	TOP OF ROCK ELEV. 589.3	
72–86	SANDSTONE, grey, med. soft, medium to fine grained, micaceous.	Newton cyclothem, Post-Allegheinian of Pennsylvanian system.
86–91	SHALE, grey, sandy, medium hard, micaceous.	
96	Water table	
91–131	SANDSTONE, grey, medium to fine grained, medium hard, micaceous.	
131–150	SHALE, black, clay, sound, hard, carbonaceous, pyritic above El. 528.5, light grey, silt, hard, calcareous below El. 528.5.	

BOTTOM OF HOLE ELEV. 511.2
DEPTH OF HOLE 150.3'
DEPTH OF OVERBURDEN 72.2'
FEET CORED 78.1'
PERCENT CORE RECOVERY 86

HOLE NO. 26

SURFACE ELEVATION 677.3

0–52	TILL, glacial, with localized lenses of sand and small gravel, compact.	Wisconsin
52–74	TILL, glacial, very sandy, mass of boulders at El. 604.3.	
74–81.8	TILL, glacial, very sandy, mass of boulders at el. 625.3.	
81.8	TOP OF ROCK ELEV. 595.5	
81.8–106.2	SANDSTONE, med. grained, weathered, greenish brown, micaceous, very soft, porous.	Newton cyclothem, Post-Allegheinian of Pennsylvanian system.

BOTTOM OF HOLE ELEV. 571.1
DEPTH OF HOLE 106.2'
DEPTH OF OVERBURDEN 81.8'
FEET CORED 24.4'
PERCENT CORE RECOVERY 66.0

WABASH RIVER BASIN

LINCOLN RESERVOIR

EMBARRASS RIVER, ILLINOIS

FOUNDATION EXPLORATIONS

CORE BORING LOGS

SHEET 5 OF 9 SHEETS

U.S. ENGINEER OFFICE, LOUISVILLE, KY

WAR DEPARTMENT

HOLE NO. 20

SURFACE ELEVATION 551.5

ALLUVIUM, sandy silt.
Water table

TOP OF ROCK ELEV. 528.8
SHALE, very soft.
LIMESTONE, gray, argillaceous, med. hard, broken.
SHALE, grey, med. hard, calcareous.
BOTTOM OF HOLE EL. 516.6

DEPTH OF HOLE	34.9'
DEPTH OF OVERBURDEN	22.7'
FEET CORED	12.2'
PERCENT CORE RECOVERY	81

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

HOLE NO. 19

SURFACE ELEVATION 554.8

TALUS, from hills of glacial till.
Water table

TOP OF ROCK ELEV. 541.3
SHALE, very soft.
LIMESTONE, med. hard, broken, dark grey.
SHALE, lime, grey, med. hard.
LIMESTONE, grey, med. hard, sound.
SHALE, clay, grey, med. hard, sound.
LIMESTONE
SHALE, silty, med. hard, light grey, calcareous.
SHALE, lime, grey, med. hard.
SANDSTONE, very fine grained, hard, calcareous.
SHALE, lime, grey, med. hard.
LIMESTONE, dark grey, med. hard.
SHALE, clay.
BOTTOM OF HOLE EL. 439.3

DEPTH OF HOLE	115.5'
DEPTH OF OVERBURDEN	13.5'
FEET CORED	102.0'
PERCENT CORE RECOVERY	94.0

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

HOLE NO. 18

SURFACE ELEVATION 551.3

ALLUVIUM, sandy silt with some small to med. gravel, loose.
Water table

TOP OF ROCK ELEV. 532.8
LIMESTONE, grey, hard, broken above El. 530.0
SHALE, silty, light grey, sound, med. hard, calcareous.
SHALE, clay, sound, med. hard, grey.
BOTTOM OF HOLE EL. 520.2

DEPTH OF HOLE	31.1'
DEPTH OF OVERBURDEN	18.5'
FEET CORED	12.6'
PERCENT CORE RECOVERY	86+

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

HOLE NO. 29

SURFACE ELEVATION 647.6

TILL, (boulder clay), clay, sand and small gravel in varying quantities.
Water table

Glacial Till (Wisconsin)

SAND, very compact, tightly packed, partially cemented.

TILL, with a high percentage of sand.

TOP OF ROCK ELEV. 539.2
SHALE, grey, soft clay, highly weathered.
LIMESTONE, grey, shal'y, hard, broken, argillaceous.
SHALE, clay, grey, very soft, weathered, calcareous.
LIMESTONE, grey, shal'y med. hard.
SHALE, silty, grey, med. hard, sound at contact.
BOTTOM OF HOLE EL. 517.5

DEPTH OF HOLE	130.1'
DEPTH OF OVERBURDEN	108.4'
FEET CORED	21.7'
PERCENT CORE RECOVERY	53

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

SURFACE EL

SURFACE EL

SURFACE EL

Newton cyclothem, Post-Alleghenian of Pennsylvanian system

Glacial Till (Wisconsin)

Newton cyclothem, Post-Alleghenian of Pennsylvanian system

HOLE NO. 27

SURFACE ELEVATION 552.6

ALLUVIUM, silt, sandy with small to med. gravel.

Water table

TOP OF ROCK ELEV. 530.6

SHALE, grey, very soft, weathered

LIMESTONE, grey, hard, argillaceous, sound below El. 524.5

SHALE, silt, grey, med. hard

SHALE, clay, grey, med. hard

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

DEPTH OF HOLE	45.9'
DEPTH OF OVERBURDEN	22.0'
BOTTOM OF HOLE EL. 506.7	
FEET CORED	23.9'
PERCENT CORE RECOVERY	82

HOLE NO. 30

SURFACE ELEVATION 571.1

TILL

Glacial Till (Wisconsin)

Water table

TOP OF ROCK ELEV. 546.9

LIMESTONE, gray, argillaceous, med. hard, sound below El. 537.7.

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

SHALE, silt, light grey, med. hard, sound, calcareous.

SHALE, clay, dark grey, med. hard, sound.

BOTTOM OF HOLE EL. 519.7	
DEPTH OF HOLE	51.4'
DEPTH OF OVERBURDEN	24.2'
FEET CORED	27.2'
PERCENT CORE RECOVERY	82

HOLE NO. 32

SURFACE ELEVATION 555.0

TILL

Glacial Till (Wisconsin)

Water table.

TOP OF ROCK ELEL. 536.0

SHALE, very soft.

LIMESTONE, gray, argillaceous, hard, sound.

SHALE, silt, grey, med hard, sound, calcareous.

SHALE, clay, dark grey, med. hard, sound.

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

BOTTOM OF HOLE EL. 518.0	
DEPTH OF HOLE	37.0'
DEPTH OF OVERBURDEN	19.0'
FEET CORED	18.0'
PERCENT CORE RECOVERY	89

HOLE NO. 31

SURFACE ELEVATION 557.2

TILL, sand, clay & gravel, in varying proportions.

Water table

Wisconsin

TOP OF ROCK ELEV. 543.5

SHALE, grey, soft.

LIMESTONE, med. hard, argillaceous.

SHALE, very soft, grey, clay, calcareous.

LIMESTONE, med. hard, grey.

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

SHALE, med. hard, dark grey, silty at top, sound at contact.

BOTTOM OF HOLE EL. 515.7	
DEPTH OF HOLE	41.5'
DEPTH OF OVERBURDEN	13.7'
FEET CORED	27.8'
PERCENT CORE RECOVERY	67

HOLE NO. 28

SURFACE ELEVATION 553.8

ALLUVIUM, silt, very sandy.

Water table

TOP OF ROCK EL. 527.7

LIMESTONE, grey, med. hard.

SHALE, med. hard, dark grey, sound, clay.

Newton cyclothem, Post-Alleghenian of Pennsylvanian system.

BOTTOM OF HOLE EL. 514.4	
DEPTH OF HOLE	39.4'
DEPTH OF OVERBURDEN	26.1'
FEET CORED	13.3'
PERCENT CORE RECOVERY	93+

WABASH RIVER BASIN

LINCOLN RESERVOIR

EMBARRASS RIVER, ILLINOIS

FOUNDATION EXPLORATIONS

CORE BORING LOGS

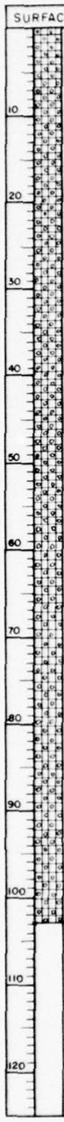
SHEET 6 OF 9 SHEETS

U.S. ENGINEER OFFICE, LOUISVILLE, KY.

WAR DEPARTMENT

HOLE NO. 33

SURFACE ELEVATION 642.1



GLACIAL TILL, sand, silt, clay and gravel in varying proportions.

BOTTOM OF HOLE EL. 539.3

DEPTH OF HOLE 102.8'

HOLE NO. 34

SURFACE ELEVATION 638.7

GLACIAL TILL, sand, gravel, clay and silt in varying proportions.

Water table

SANDSTONE, very soft, fine grained, brown, highly weathered, micaceous. — No core

TOP OF ROCK EL. 573.3

SANDSTONE, soft, fine to medium grained, buff, weathered thin bedded, micaceous, pyritic. — Good core

SHALE, soft to medium hard, clayey light to dark grey, sound pyritic.

LIMESTONE AND SHALE, brecciated zone, hard.

SHALE, medium hard, bony, clayey, varibly carbonaceous.

LIMESTONE, hard, fine grained, impure.

SHALE, clay, soft to medium hard, hackley fracture, grey and variegated.

LIMESTONE, medium hard, fine grained shal'y, grey, very fossiliferous.

SHALE, soft to medium hard, clayey, dark grey, even and well bedded.

Newton cyclothem of Post-Alleghenian series of Pennsylvanian system.

LIMESTONE, as elevation 518.9 - 517.6.

SHALE, medium hard, clayey, grey, well bedded.

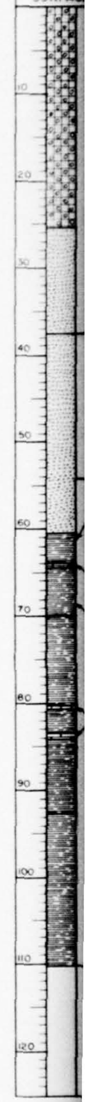
BOTTOM OF HOLE EL. 497.4

DEPTH OF HOLE	141.3'
DEPTH OF OVERBURDEN	65.4'
FEET CORED	75.9'
PERCENT CORE RECOVERY	87+

RESULTS OF PRESSURE TEST

EL. OF PACKERS		PRESSURE IN LBS. PER SQ. INCH	LOSS IN GALLONS FOR TIME INTERVAL IN MINUTES		
TOP	BOTTOM		5	10	15
538.7	533.7	10	33	-	-
533.7	497.4	10	11	-	-
533.7	497.4	20	14	-	-

SURFACE



No core

Good core

Newton cyclothem of Post-Alleghenian series of Pennsylvanion system.

TEST	
GALLONS FOR TIME	
VAL IN MINUTES	
10	15
-	-
-	-
-	-

CORPS OF ENGINEERS, U.S. ARMY

HOLE NO. 35

SURFACE ELEVATION 619.2

GLACIAL TILL, sand, gravel, clay, and silt in varying proportions.

SANDSTONE, very soft, fine grained, brown, micaceous highly weathered. — No core

TOP OF ROCK EL. 581.6

SANDSTONE, soft, fine to medium grained, brown, micaceous, highly weathered below elevation 573.5. No core between elevation 573.5 and elevation 558.7.

Water table

SHALE, soft to medium hard, clayey, grey, bony near elevation 555.2

LIMESTONE, impure, hard, dark grey, fossiliferous at base.

SHALE, soft to medium hard, silty, light grey, calcareous.

SHALE, medium soft, silty, dark grey, calcareous.

LIMESTONE, nodular, impure.

SHALE, soft to medium hard, silty, light grey. — Newton cyclothem of Post-Alleghenian series of Pennsylvanian system.

SHALE, medium hard, clayey dark grey, fossiliferous, calcareous, pyritic, silty between elevation 521.0 and 512.0.

BOTTOM OF HOLE EL. 509.0
DEPTH OF HOLE 110.2'
DEPTH OF OVERBURDEN 37.6'
FEET CORED 72.6'
PERCENT CORE RECOVERY 56

HOLE NO. 36

SURFACE ELEVATION 618.6

GLACIAL TILL, sand, gravel gravel, clay and silt in varying proportions.

SANDSTONE, very soft, fine grained, brown, highly weathered, micaceous. — No core

TOP OF ROCK EL. 578.4 — Newton cyclothem of Post-Alleghenian series of Pennsylvanian system.

SANDSTONE, soft, fine to medium grained, buff, weathered, thin bedded.

Water table

LIMESTONE, hard, crystalline, grey, thin bedded, slightly fossiliferous.

SHALE, clay, medium hard, silty dark grey, calcareous.

LIMESTONE, as above, except mostly argillaceous.

SHALE, clay as above except light grey.

LIMESTONE, impure.

SHALE, medium soft, silty, grey, calcareous.

LIMESTONE, hard, nodular, grey.

SHALE, as above except soft.

LIMESTONE, medium hard brecciated, greenish grey

SHALE, medium hard, clayey grey, calcareous.

LIMESTONE, grey, medium hard fossiliferous.

SHALE, medium hard, silty, grey, sound at contact.

BOTTOM OF HOLE EL. 519.2
DEPTH OF HOLE 99.4'
DEPTH OF OVERBURDEN 40.2'
FEET CORED 59.2'
PERCENT CORE RECOVERY 83.0

RESULTS OF PRESSURE TEST

EL. OF PACKERS		PRESSURE IN LBS	LOSS IN GALLONS FOR TIME INTERVAL IN MINUTES		
TOP	BOTTOM	PER SQ INCH	5	10	15
568.0	563.0	10	38	-	-
550.0	545.0	10	2	-	-

WABASH RIVER BASIN

LINCOLN RESERVOIR

EMBARRASS RIVER, ILLINOIS

FOUNDATION EXPLORATIONS

CORE BORING LOGS

SHEET 7 OF 9 SHEETS

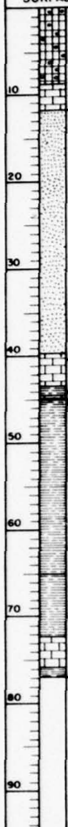
U.S. ENGINEER OFFICE, LOUISVILLE, KY

PLATE E-14

WAR DEPARTMENT

HOLE NO. 37

SURFACE ELEVATION 596.4



GLACIAL TILL, sand, gravel, clay, and silt in varying quantities.

SANDSTONE, very soft, weathered, fine grained, brown — No core.

TOP OF ROCK EL. 584.6

SANDSTONE, soft, fine to medium grain, buff, micaceous, thin bedded.

Water table

LIMESTONE, hard, fine grain, crystalline to slightly argillaceous.

INDURATED CLAY, medium, hard, silty, black, carbonaceous

LIMESTONE, hard, fine grained, impure, grey.

SHALE, clay, medium, hard, silty, grey, calcareous.

SHALE, as above except, slightly impregnated with nodular limestone.

LIMESTONE, hard, argillaceous, grey fossiliferous

SHALE

BOTTOM OF HOLE EL. 520.0

DEPTH OF HOLE	76.4'
DEPTH OF OVERBURDEN	11.8'
FEET CORED	64.6'
PERCENT CORE RECOVERY	81.0

RESULTS OF PRESSURE TEST

EL. OF PACKERS TOP	EL. OF PACKERS BOTTOM	PRESSURE IN LBS. PER SQ. INCH	LOSS IN GALLONS FOR TIME INTERVAL IN MINUTES 5	10	15
576.4	571.4	10	14	23	-
549.4	544.4	10	0	1	-

HOLE NO. 38

SURFACE ELEVATION 549.7

Water table

ALLUVIUM, silt, sandy, clayey and plastic near top, sandy silt with small to medium gravel below elevation 547.7.

TOP OF ROCK EL. 528.8 — Newton cyclothem of Post Alleghenian series of Pennsylvanian system.

INDURATED CLAY, soft, silty, grey weathered.

LIMESTONE, hard, argillaceous, fossiliferous, grey.

SHALE, medium soft, silty, grey, calcareous.

LIMESTONE, medium soft to hard, argillaceous, dark grey, fossiliferous.

INDURATED CLAY, as above and calcareous.

SHALE, medium hard, clayey, dark grey, fossiliferous.

BOTTOM OF HOLE EL. 492.4

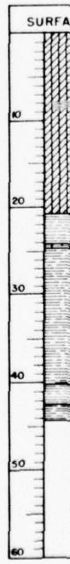
DEPTH OF HOLE	57.3'
DEPTH OF OVERBURDEN	20.9'
FEET CORED	36.4'
PERCENT CORE RECOVERY	88.0

RESULTS OF PRESSURE TEST

EL. OF PACKERS TOP	EL. OF PACKERS BOTTOM	PRESSURE IN LBS. PER SQ. INCH	LOSS IN GALLONS FOR TIME INTERVAL IN MINUTES 5	10	15
524.7	519.7	10	0		
519.7	492.4	10	0		

HOLE NO. 39

SURFACE ELEVATION 551.5



Water table

ALLUVIUM, silt, sandy, clayey and plastic near top. Sandy silt with small to medium gravel below elevation 548.5.

TOP OF ROCK EL. 530.6

INDURATED CLAY, hard, silty, light grey, highly calcareous. — Newton cyclothem of Post Alleghenian series of Pennsylvanian system.

LIMESTONE, hard, fine grained crystalline, grey.

SHALE, medium hard, silty, grey slightly calcareous.

SHALE, hard, sandy, grey, micaceous, fossiliferous, calcareous, carbonaceous near bottom.

SHALE, medium hard, clayey, grey, carbonaceous.

BOTTOM OF HOLE EL. 507.3

DEPTH OF HOLE	44.2'
DEPTH OF OVERBURDEN	20.9'
FEET CORED	23.3'
PERCENT CORE RECOVERY	80+

Newton cyclothem of Post Alleghenian series of Pennsyl- vanian system.

TEST
GALLONS FOR TIME
VAL IN MINUTES
10 15

Newton cyclothem of Post Alleghenian series of Pennsyl- vanian system.

HOLE NO. 40

SURFACE ELEVATION 552.3

ALLUVIUM, sandy silt, with small to medium gravel.
Water table
ALLUVIUM, silty clay, plastic grey.
SAND, fine to coarse grain, silty.
TOP OF ROCK EL. 529.8
INDURATED CLAY SHALE, silty, soft, light grey, weathered.
LIMESTONE, hard, argillaceous, grey, fossiliferous.
SHALE, medium hard, silty, light grey, calcareous.
SHALE, medium hard, clayey dark grey, carbonaceous.
BOTTOM OF HOLE EL. 516.3

DEPTH OF HOLE	36.0'
DEPTH OF OVERBURDEN	22.5'
FEET CORED	13.5'
PERCENT CORE RECOVERY	92+

Newton cyclothem of Post Alleghenian series of Pennsyl- vanian system.

RESULTS OF PRESSURE TEST

EL. OF PACKERS TOP	BOTTOM	PRESSURE IN LBS. PER. SQ. INCH	LOSS IN GALLONS FOR TIME INTERVAL IN MINUTES 5	10	15
526.0	521.0	10	3	-	-
521.0	516.3	25	0	-	-

HOLE NO. 41

SURFACE ELEVATION 550.0

Water table
ALLUVIUM, silty, sandy and clayey, soft, plastic.
TOP OF ROCK EL. 526.9
INDURATED CLAY SHALE, soft, silty, light grey, calcareous, weathered at top.
LIMESTONE, hard argillaceous, light grey, fossiliferous.
SHALE, medium hard, silty, light grey, calcareous.
SHALE, medium hard, clayey, dark grey, carbonaceous, fossiliferous.
BOTTOM OF HOLE EL. 497.2

DEPTH OF HOLE	52.8'
DEPTH OF OVERBURDEN	23.1'
FEET CORED	29.7'
PERCENT CORE RECOVERY	96+

Newton cyclothem of Post-Alleghenian series of Pennsylvanian system.

RESULTS OF PRESSURE TEST

EL. OF PACKERS TOP	BOTTOM	PRESSURE IN LBS. PER SQ. INCH	LOSS IN GALLONS FOR TIME INTERVAL IN MINUTES 5	10	15
523.0	518.0	10	3	-	-
518.0	497.2	10	0	-	-

HOLE NO. 42

SURFACE ELEVATION 552.3

Water table
ALLUVIUM, sand, silt and clay, soft.
SAND, silt, gravel and small boulders.
SHALE, very soft, clayey, light grey, highly weathered.
TOP OF ROCK EL. 521.9
SHALE as above, soft not so weathered.
LIMESTONE, hard, fine grained fossiliferous, grey, impure.
SHALE, medium soft, sandy below elevation 516.4, grey sound, fossiliferous, carbonaceous, slightly calcareous.
SHALE, medium hard, clayey dark grey, carbonaceous, fossiliferous, slightly calcareous.
LIMESTONE, hard, shaly, dark grey, impure, highly fossiliferous.
BOTTOM OF HOLE EL. 505.0

DEPTH OF HOLE	47.3'
DEPTH OF OVERBURDEN	30.4'
FEET CORED	16.9'
PERCENT CORE RECOVERY	78+

No core.

RESULTS OF PRESSURE TEST

EL. OF PACKERS TOP	BOTTOM	PRESSURE IN LBS. PER. SQ. INCH	LOSS IN GALLONS FOR TIME INTERVAL IN MINUTES 5	10	15
522.3	517.3	10	0	-	-
517.3	505.0	10	1.0	-	-

WABASH RIVER BASIN

LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS

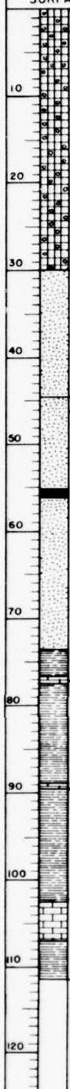
FOUNDATION EXPLORATIONS
CORE BORING LOGS

SHEET 8 OF 9 SHEETS

U.S. ENGINEER OFFICE, LOUISVILLE, KY.

HOLE NO. 43

SURFACE ELEVATION 609.8



GLACIAL TILL, sand, gravel, clay and silt in varying proportions. — Wisconsin

SANDSTONE, shaly, highly weathered, grey soft. — No core.

TOP OF ROCK EL. 565.2
Water table
SANDSTONE, medium soft, fine grain, grey, thin bedded, shaly, micaceous, slightly cross bedded. — Good core.
THIN COAL SEAMS

SANDSTONE, medium soft, fine grained.

SHALE, medium hard, clayey, grey, thin bedded, carbonaceous, pyritic.
LIMESTONE, impure, hard, fine grain, dark grey.

SHALE, hard, silty, light grey calcareous, impregnated with limestone nodules below elevation 511.0.
LIMESTONE, impure, hard.

SHALE, hard, silty, light grey, calcareous, impregnated with limestone nodules below elevation 511.0.
LIMESTONE, hard, fine grain, grey, thin bedded, shaly.

SHALE, hard, silty, light grey, calcareous.

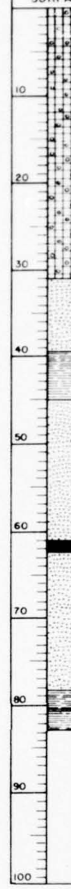
BOTTOM OF HOLE EL. 498.3
DEPTH OF HOLE 111.5'
DEPTH OF OVERBURDEN 44.6'
FEET CORED 66.9'
PERCENT CORE RECOVERY 98+

RESULTS OF PRESSURE TEST

EL. OF PACKERS		PRESSURE IN LBS. PER SQ INCH	LOSS IN GALLONS FOR TIME INTERVAL IN MINUTES		
TOP	BOTTOM		5	10	15
550.0	545.0	10	1.5	-	-
545.0	498.3	10	1.0	-	-

HOLE NO. 44

SURFACE ELEVATION 614.7



GLACIAL TILL, sand, gravel, clay and silt in varying proportions. — Wisc

SANDSTONE, very soft, highly weathered, fine grained, brown, micaceous. — Fisht no co

TOP OF ROCK EL. 575.2
SHALE, medium soft, sandy, dark grey, micaceous. — Good

SANDSTONE, medium soft, fine grained, grey, thin bedded, micaceous, medium hard below elevation 549.0.
Water table

THIN COAL SEAMS

SANDSTONE, as above.

SHALE, interbedded, medium hard, sandy, dark grey.
LIMESTONE (0.3'), impure, hard fine grained, dark grey.
SHALE, medium hard, clayey, dark grey, carbonaceous, calcareous.
BOTTOM OF HOLE EL. 532.1
DEPTH OF HOLE 82.6'
DEPTH OF OVERBURDEN 39.5'
FEET CORED 43.1'
PERCENT CORE RECOVERY 94+

2

HOLE NO. 44

SURFACE ELEVATION 614.7

GLACIAL TILL, sand, gravel, clay and silt in varying proportions. — Wisconsin

SANDSTONE, very soft, highly weathered, fine grained, brown, micaceous. — Fishtail drilled no core.

TOP OF ROCK EL. 575.2

SHALE, medium soft, sandy, dark grey, micaceous. — Good core.

SANDSTONE, medium soft, fine grained, grey, thin bedded, micaceous, medium hard below elevation 549.0.

Water table

THIN COAL SEAMS

SANDSTONE, as above.

SHALE, interbedded, medium hard, sandy, dark grey.

LIMESTONE (0.3'), impure, hard fine grained, dark grey.

SHALE, medium hard, clayey, dark grey, carbonaceous, calcareous.

BOTTOM OF HOLE EL. 532.1

DEPTH OF HOLE	82.6'
DEPTH OF OVERBURDEN	39.5'
FEET CORED	43.1'
PERCENT CORE RECOVERY	94+

HOLE NO. 45

SURFACE ELEVATION 621.6

10 20 30 40 50 60 70 80 90 100

GLACIAL TILL, sand, gravel, clay and silt in varying proportions. — Wisconsin

Newton cyclothem, Post-Alleghenian seris of Pennsylvanian system.

TOP OF ROCK EL. 569.0

SHALE, silty, sandy, medium soft, grey, thin bedded, weathered, micaceous.

Water table

SANDSTONE, medium soft, fine fine grained, light grey, slightly shaly above elevation 561.0, medium hard below elevation 560.0, micaceous.

SHALE and SANDSTONE, interbedded, medium hard, fine grained, dark grey, micaceous.

SHALE, hard, clayey, black carbonaceous, slightly calcareous, sound.

BOTTOM OF HOLE EL. 532.9

DEPTH OF HOLE	88.7'
DEPTH OF OVERBURDEN	52.6'
FEET CORED	36.1'
PERCENT CORE RECOVERY	91+

RESULTS OF PRESSURE TEST

EL. OF PACKERS		PRESSURE IN LBS. PER SQ. INCH	LOSS IN GALLONS FOR TIME INTERVAL IN MINUTES		
TOP	BOTTOM		5	10	15
561.6	556.6	15	0.5	-	-
556.6	532.9	15	2.25		

WABASH RIVER BASIN

LINCOLN RESERVOIR

EMBARRASS RIVER, ILLINOIS

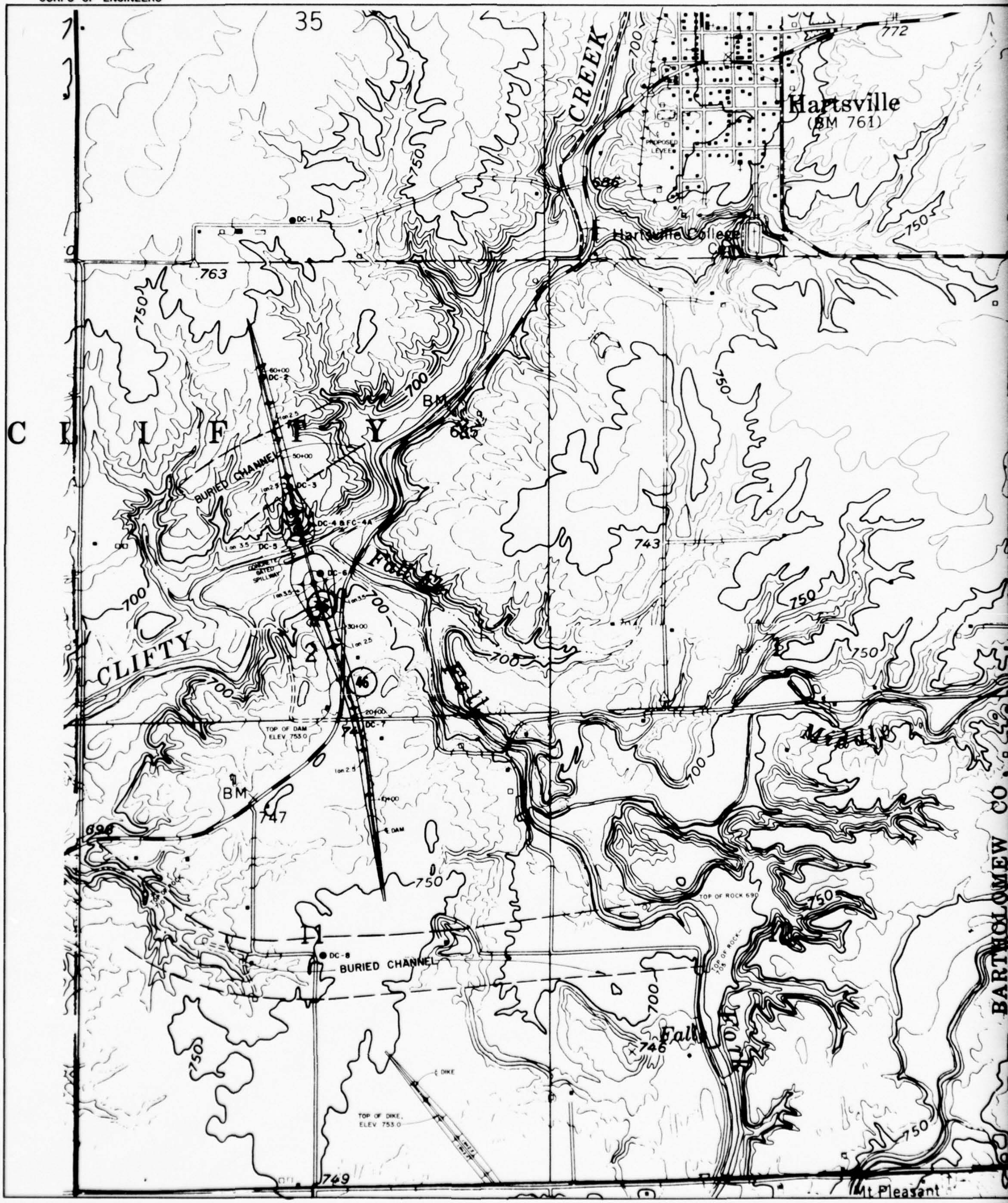
FOUNDATION EXPLORATIONS

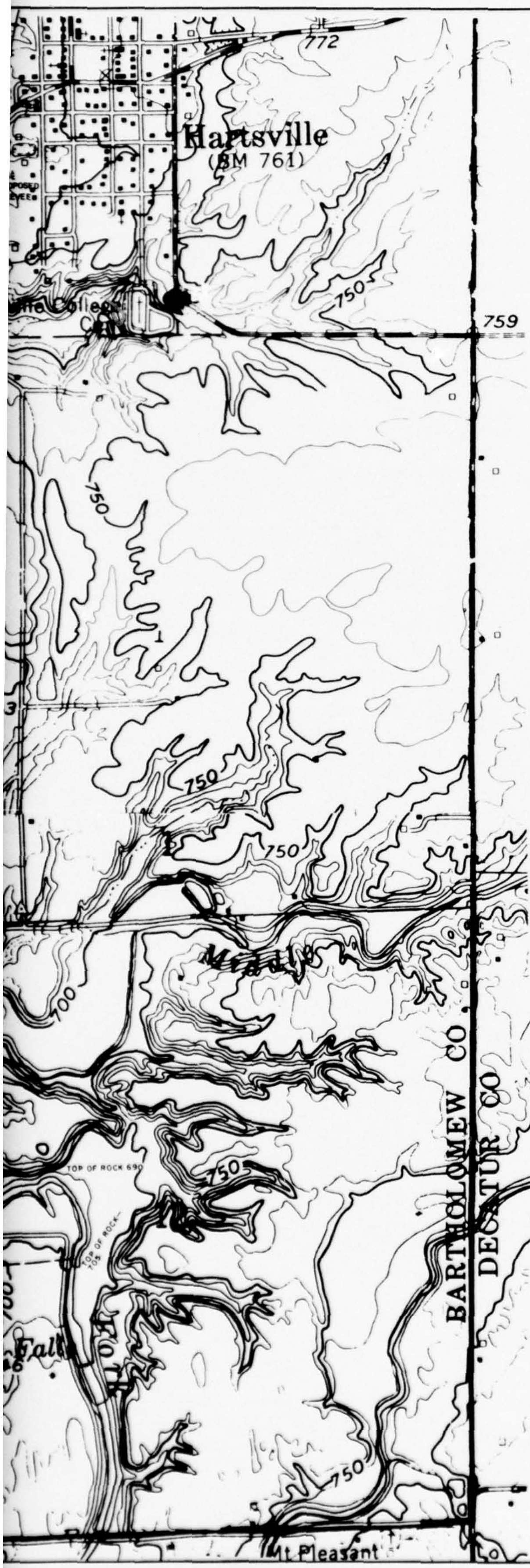
CORE BORING LOGS

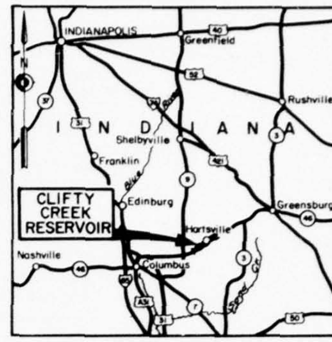
SHEET 9 OF 9 SHEETS

U.S. ENGINEER OFFICE, LOUISVILLE, KY.

CORPS OF ENGINEERS







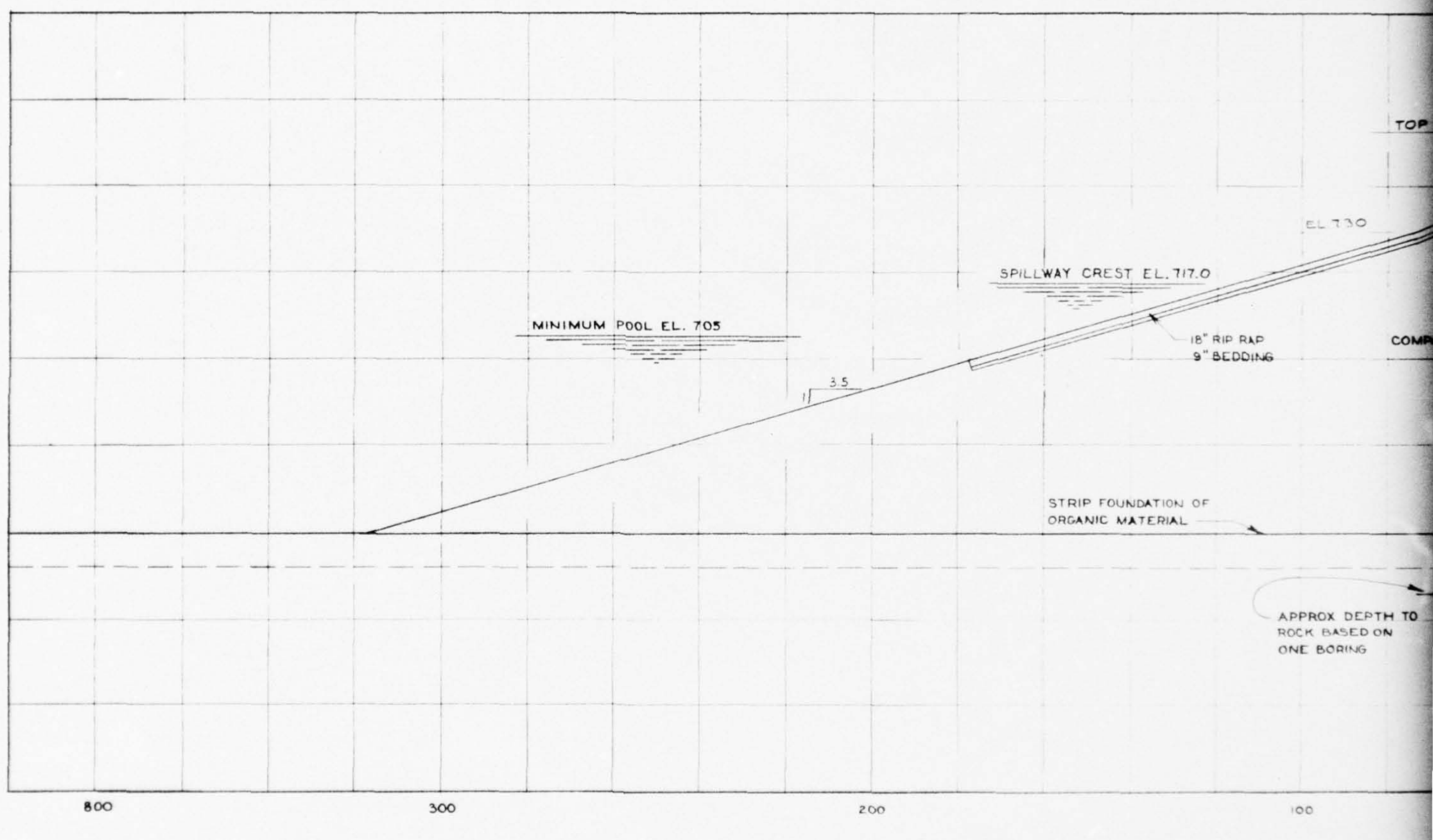
VICINITY MAP

SCALE IN MILES

REVISION	DATE	DESCRIPTION	BY

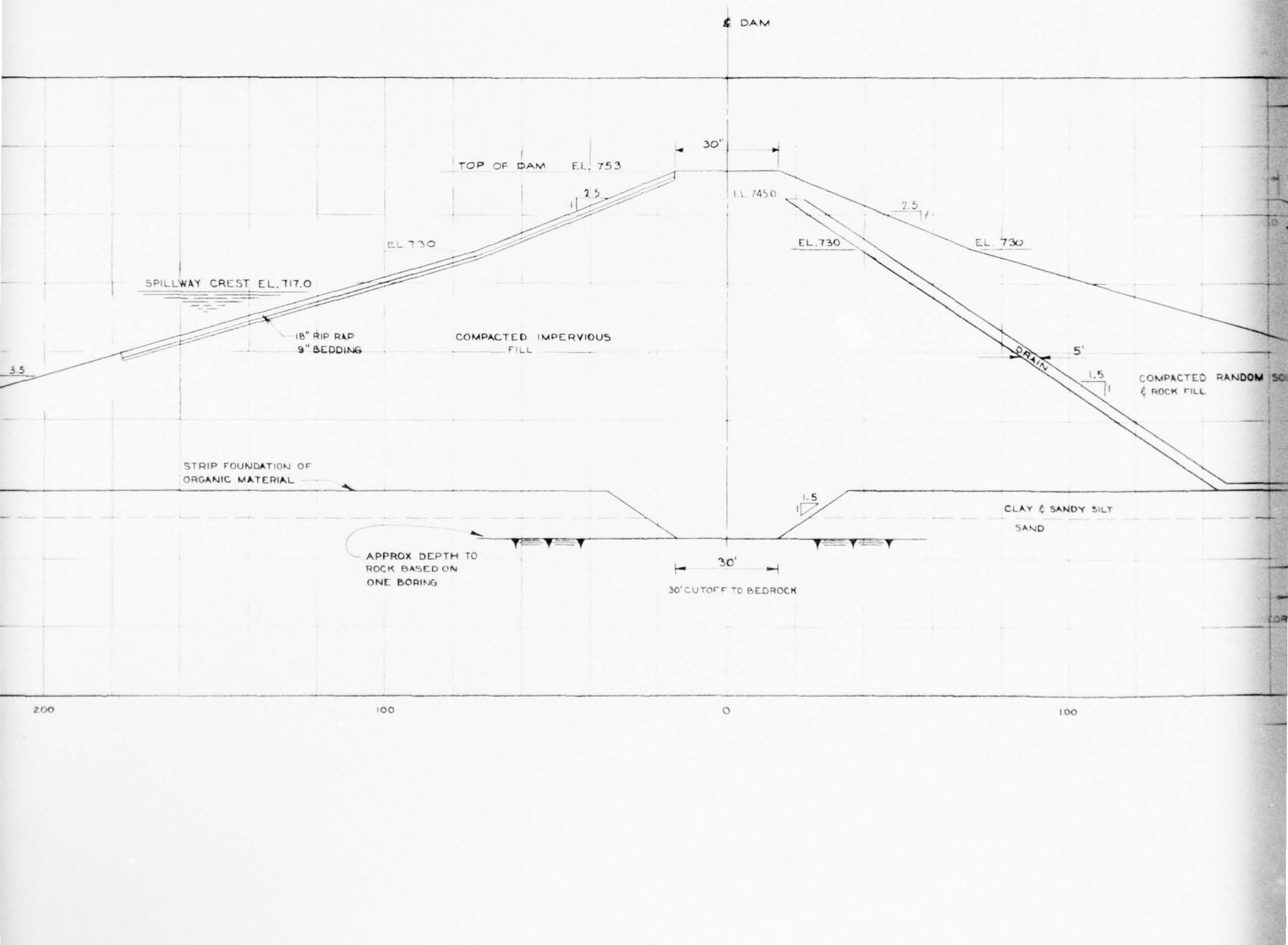
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

DESIGNED:	WABASH RIVER BASIN
DRAWN: J.E.N. TRACED:	CLIFTY CREEK RESERVOIR CLIFTY CREEK, INDIANA
CHECKED:	LOCATION OF BORINGS AND BURIED CHANNELS
SUBMITTED:	
APPROVAL RECM.:	APPROVED: DATE
ASST. CHIEF ENGINEERING DIV.	COL., CORPS OF ENGINEERS DISTRICT ENGINEER
APPROVED:	SCALE:
CHIEF, ENGINEERING DIVISION	DRAWING NUMBER



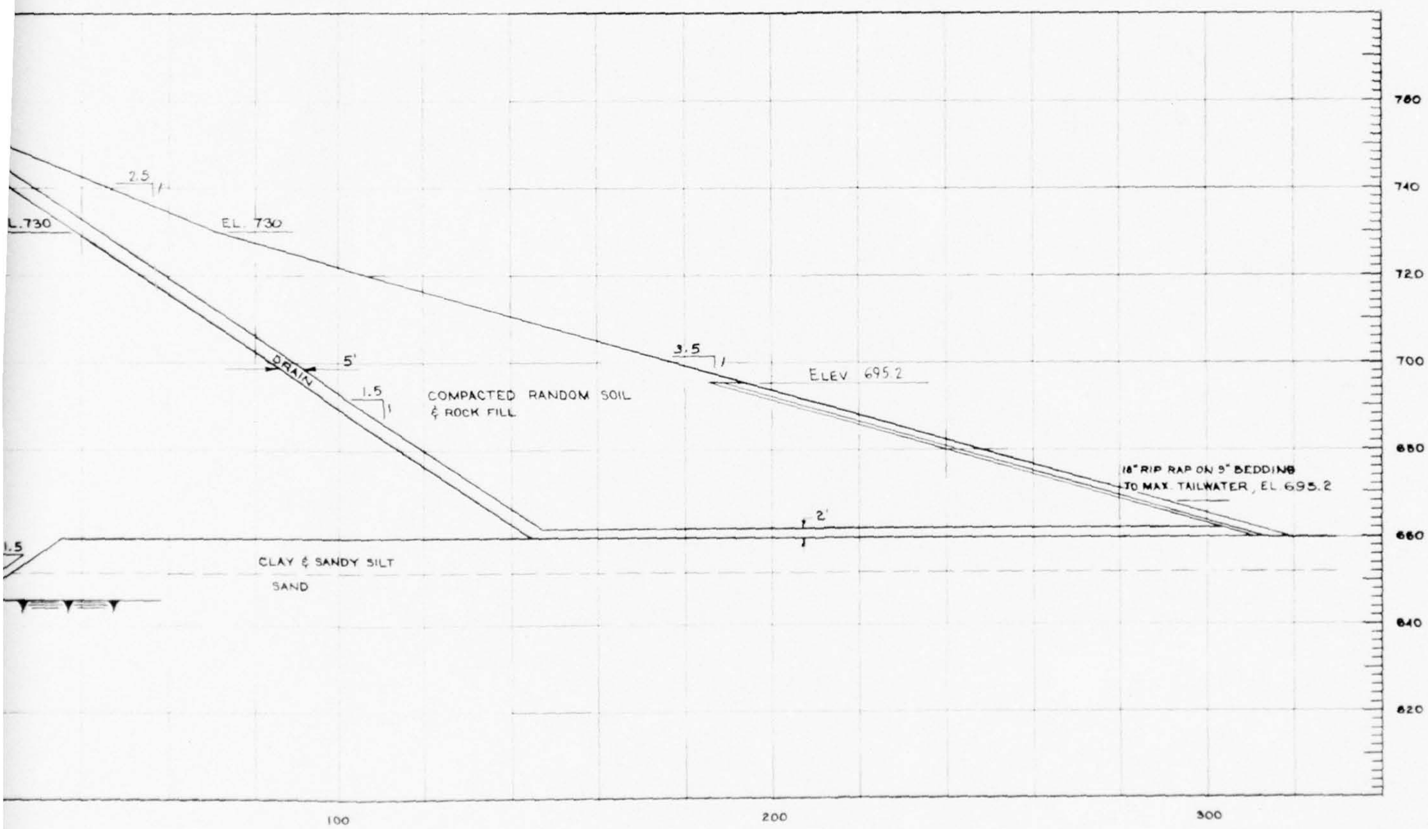
TOP
EL 730
SPILLWAY CREST EL. 717.0
MINIMUM POOL EL. 705
18" RIP RAP
9" BEDDING
COMP
3.5
1
STRIP FOUNDATION OF
ORGANIC MATERIAL
APPROX DEPTH TO
ROCK BASED ON
ONE BORING
800
300
200
100

2



℄ DAM
30'
TOP OF DAM EL. 753
2.5
1
EL. 745.0
2.5
1
EL. 730
EL. 730
EL. 730
SPILLWAY CREST EL. 717.0
18" RIP RAP
9" BEDDING
COMPACTED IMPERVIOUS
FILL
3.5
DRAIN
5'
1.5
1
COMPACTED RANDOM SO
& ROCK FILL
STRIP FOUNDATION OF
ORGANIC MATERIAL
1.5
1
CLAY & SANDY SILT
SAND
APPROX DEPTH TO
ROCK BASED ON
ONE BORING
30'
30' CUTOFF TO BEDROCK
200
100
0
100

3



WABASH RIVER BASIN

CLIFTY CREEK RESERVOIR

CLIFTY CREEK, INDIANA

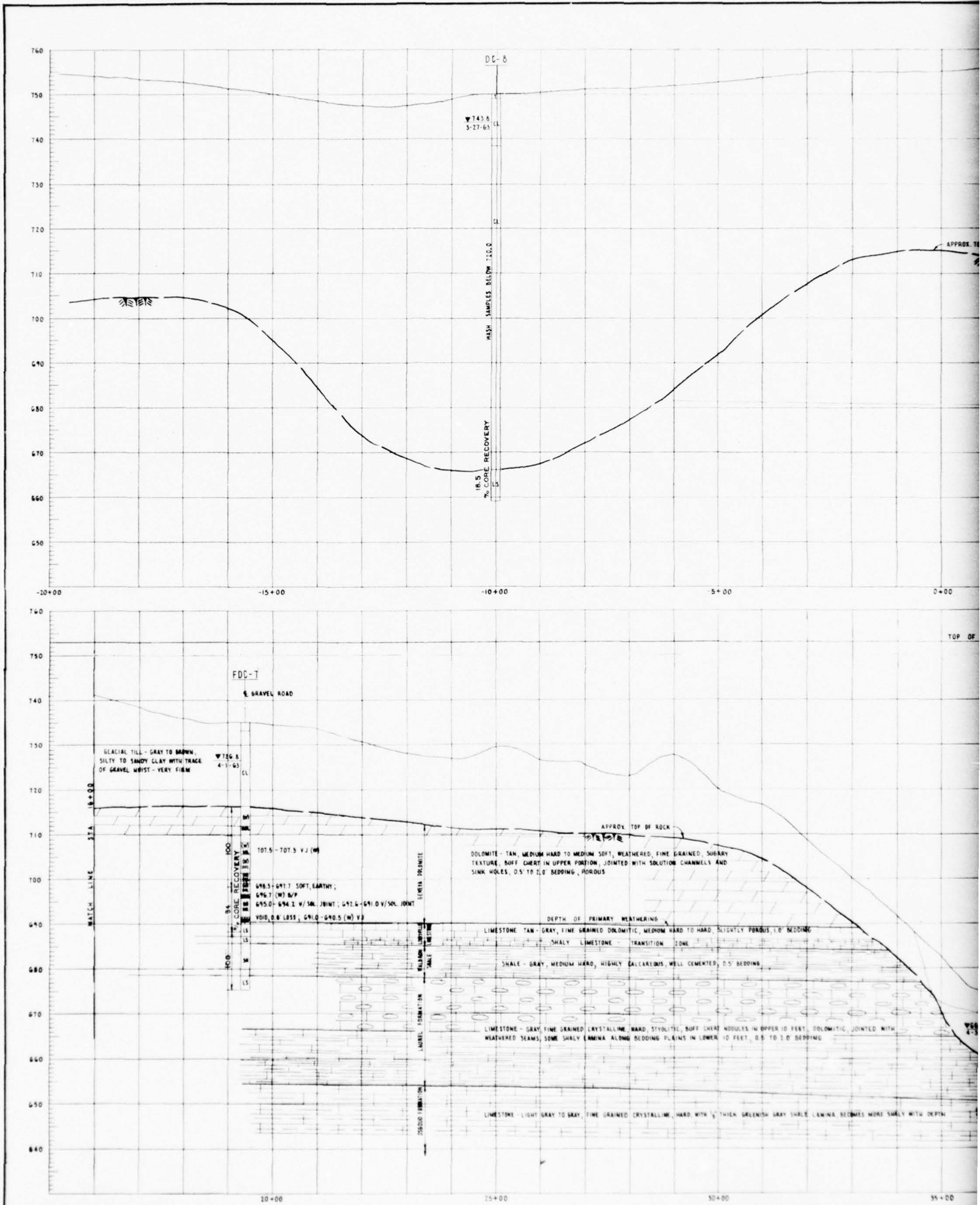
SECTION OF DAM

DR. BY E.J.M.

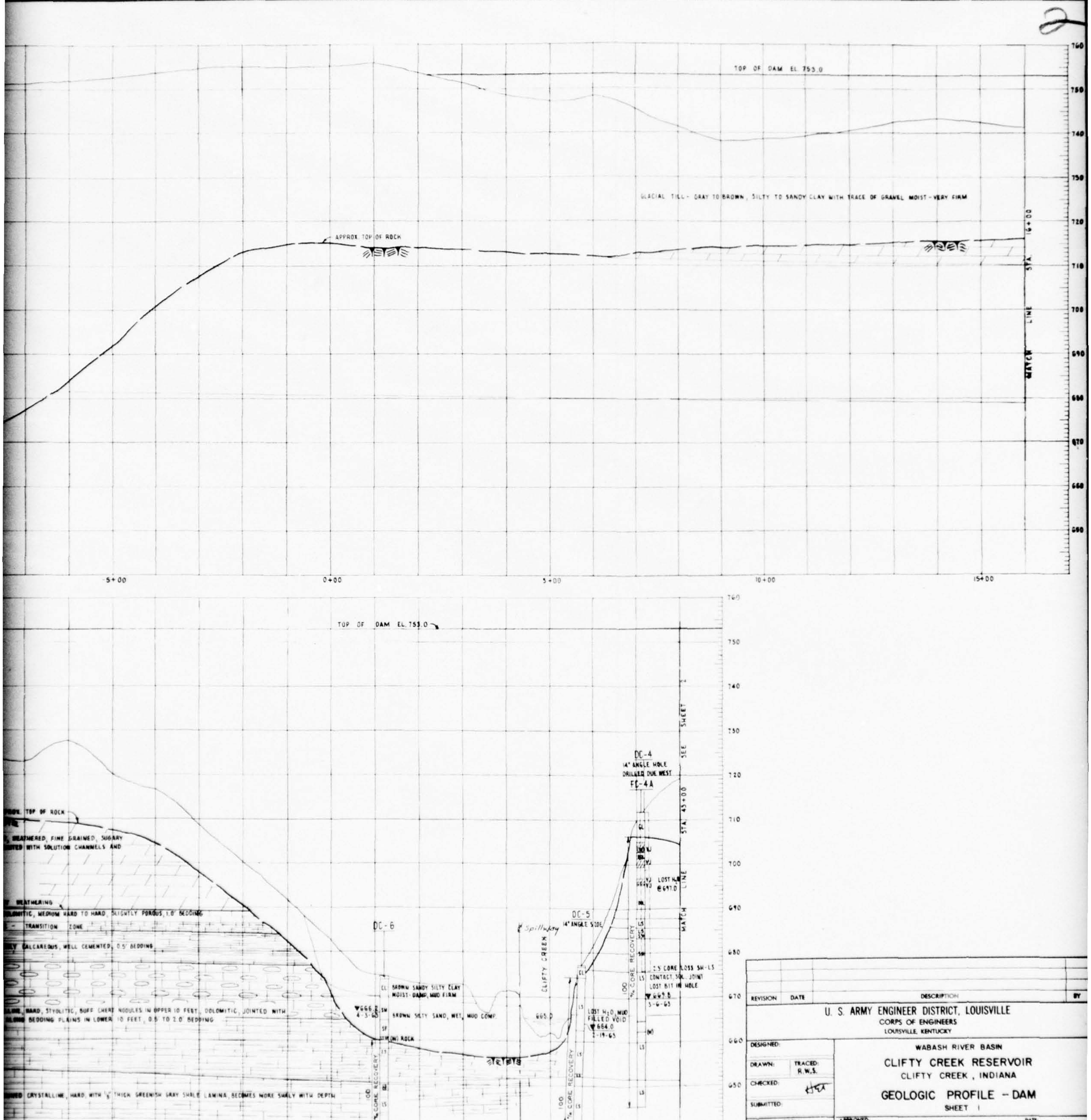
TR. BY JNP

PLATE E-18

CORPS OF ENGINEERS



U.S. ARMY



REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

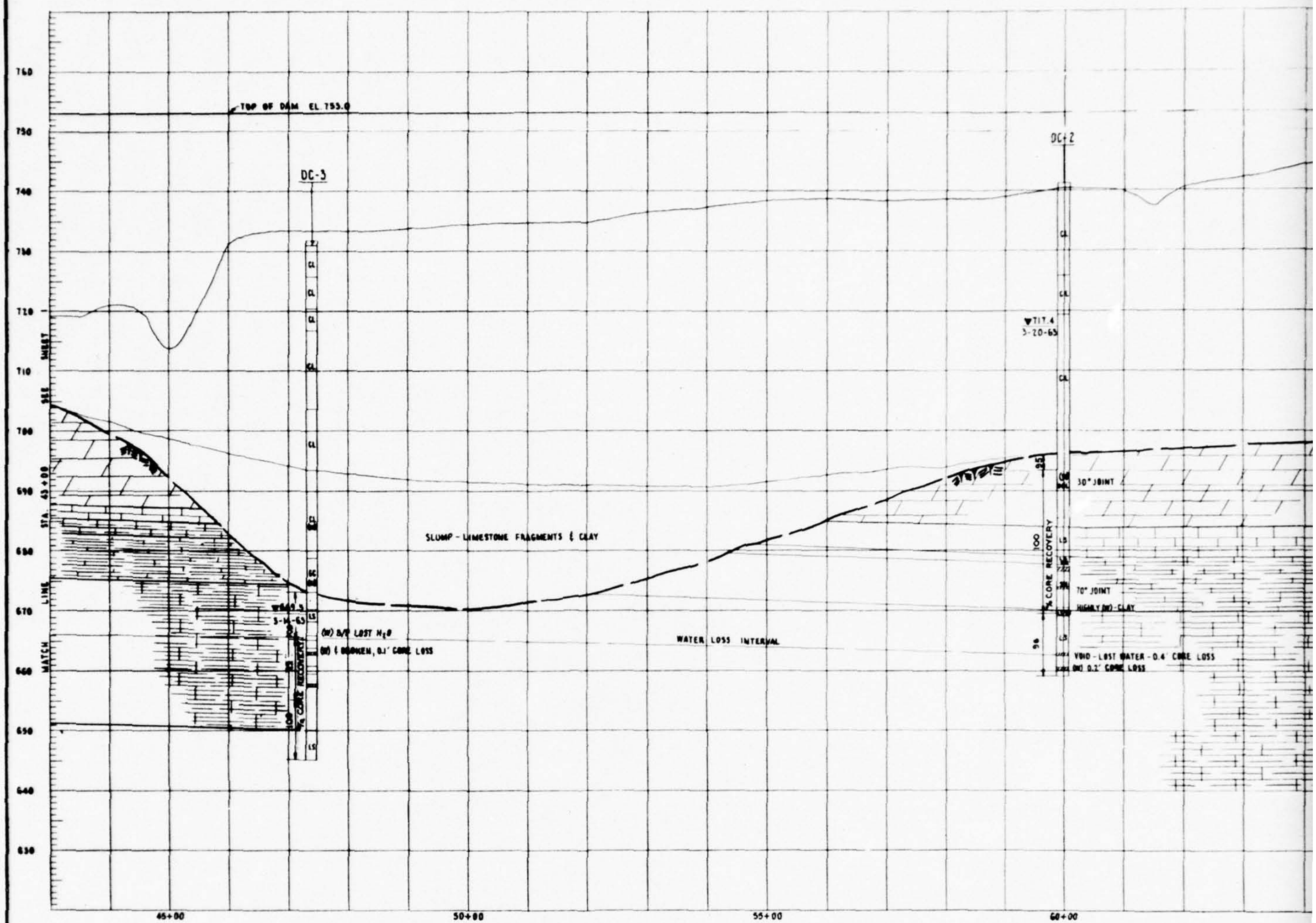
DESIGNED:
DRAWN: TRACED: R.W.S.
CHECKED: HEA
SUBMITTED:
APPROVAL RECM: ASST. CHIEF ENGINEERING DIV.
APPROVED: CHIEF ENGINEERING DIVISION

WABASH RIVER BASIN
CLIFTY CREEK RESERVOIR
CLIFTY CREEK, INDIANA
GEOLOGIC PROFILE - DAM
SHEET 1

APPROVED: COL., CORPS OF ENGINEERS DISTRICT ENGINEER
DATE:
SCALE:
DRAWING NUMBER

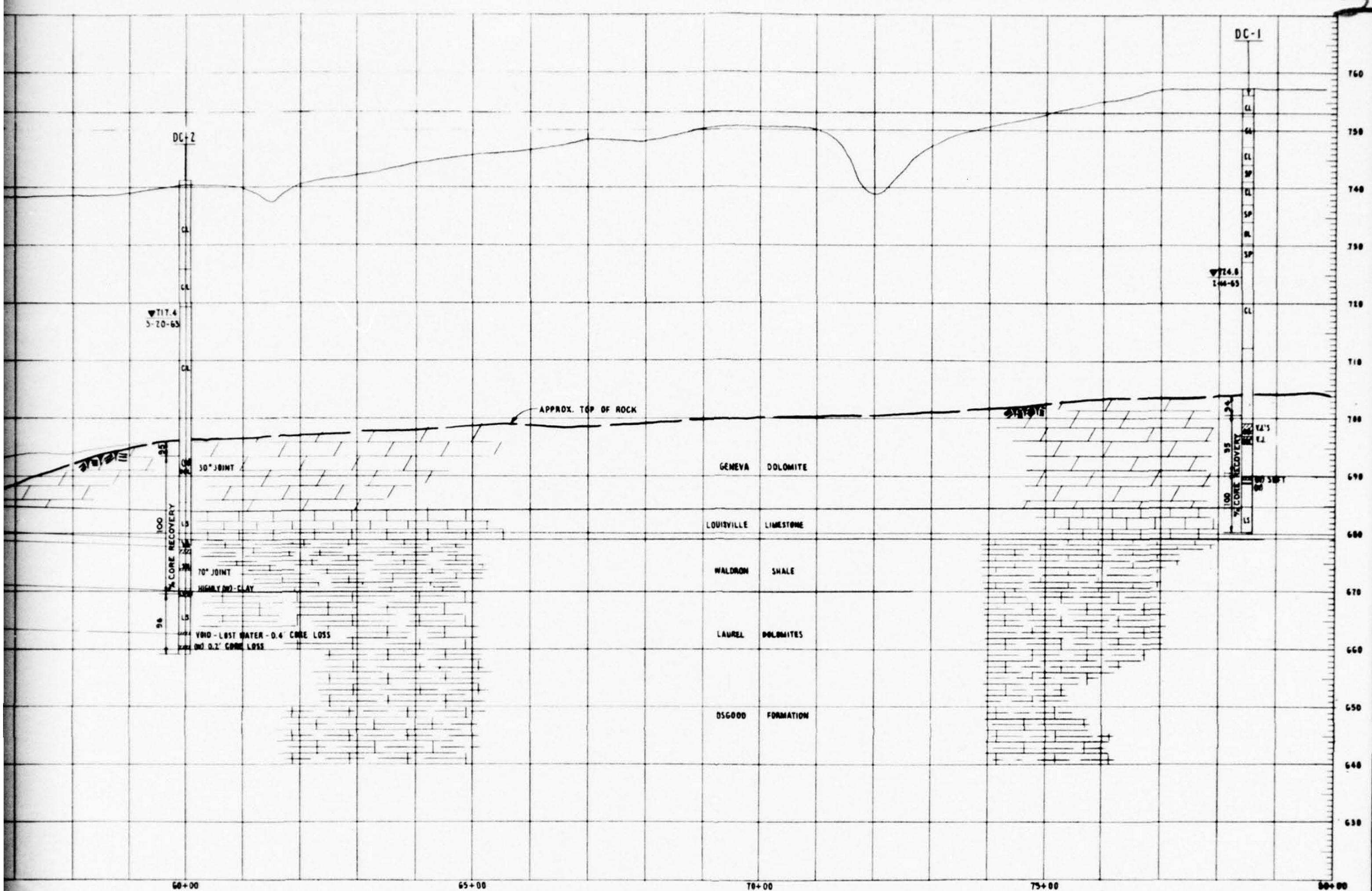
PLATE E-19

CORPS OF ENGINEERS



Army—Ohio Dailing, Cinti, Ohio, 6-19-65—900

U.S. ARMY



REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

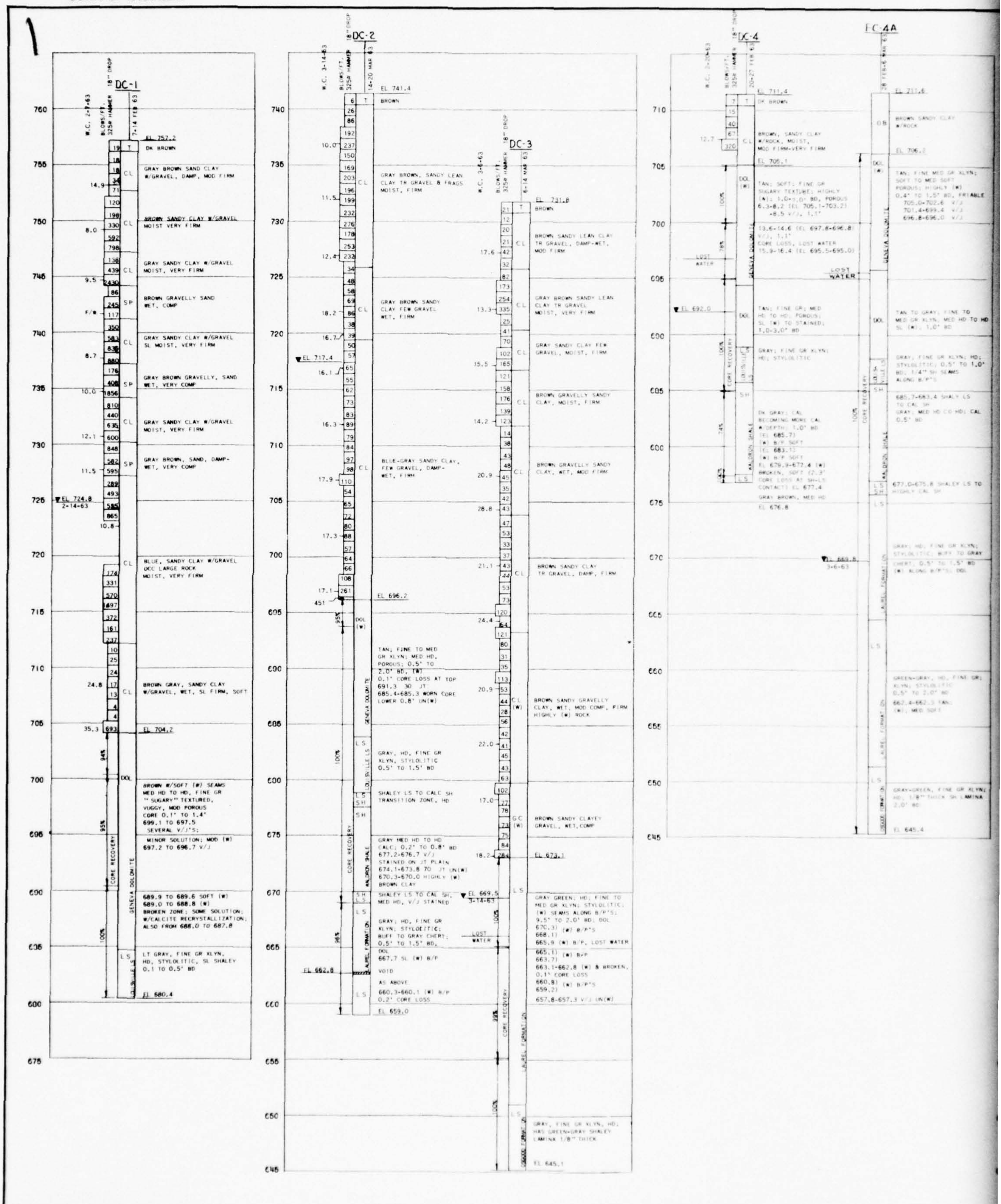
DESIGNED:
DRAWN:
TRACED: R.H.S
CHECKED:
SUBMITTED:

WABASH RIVER BASIN
CLIFTY CREEK RESERVOIR
CLIFTY CREEK, INDIANA
GEOLOGIC PROFILE - DAM
SHEET 2

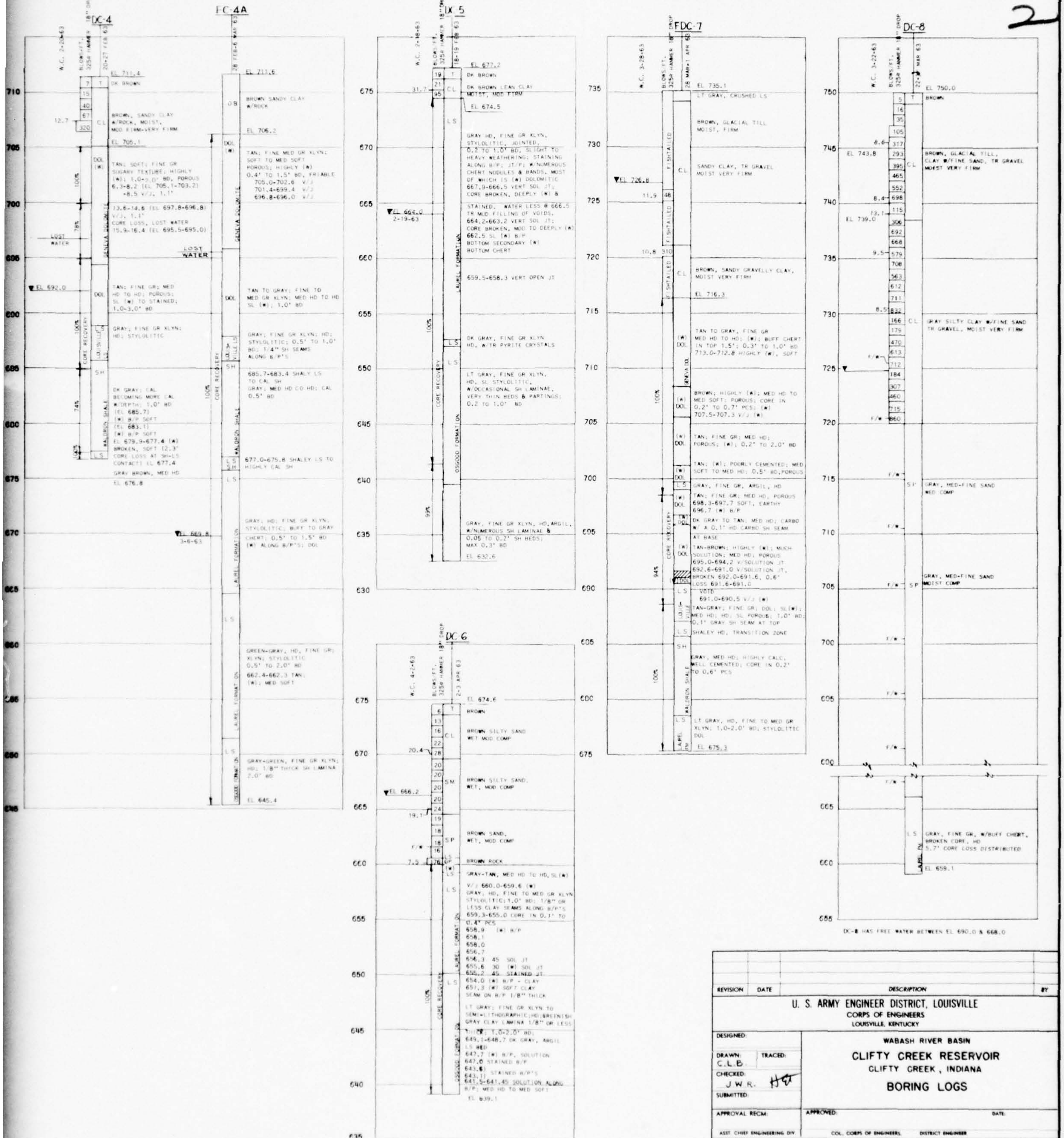
APPROVAL RECM:
ASST. CHIEF ENGINEERING DIV.
APPROVED:
DATE:
COL., CORPS OF ENGINEERS DISTRICT ENGINEER
APPROVED:
CHIEF, ENGINEERING DIVISION
SCALE:
DRAWING NUMBER

PLATE E-20

CORPS OF ENGINEERS



U.S. ARMY



REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

DESIGNED:
DRAWN: C.L.B. TRACED:
CHECKED: J.W.R.
SUBMITTED:

WABASH RIVER BASIN
CLIFTY CREEK RESERVOIR
CLIFTY CREEK, INDIANA
BORING LOGS

APPROVAL RECM: | APPROVED: | DATE:
ASST. CHIEF ENGINEERING DIV. | COL. CORPS OF ENGINEERS DISTRICT ENGINEER
APPROVED: | SCALE: | DRAWING NUMBER
CHIEF, ENGINEERING DIVISION

PLATE E-21

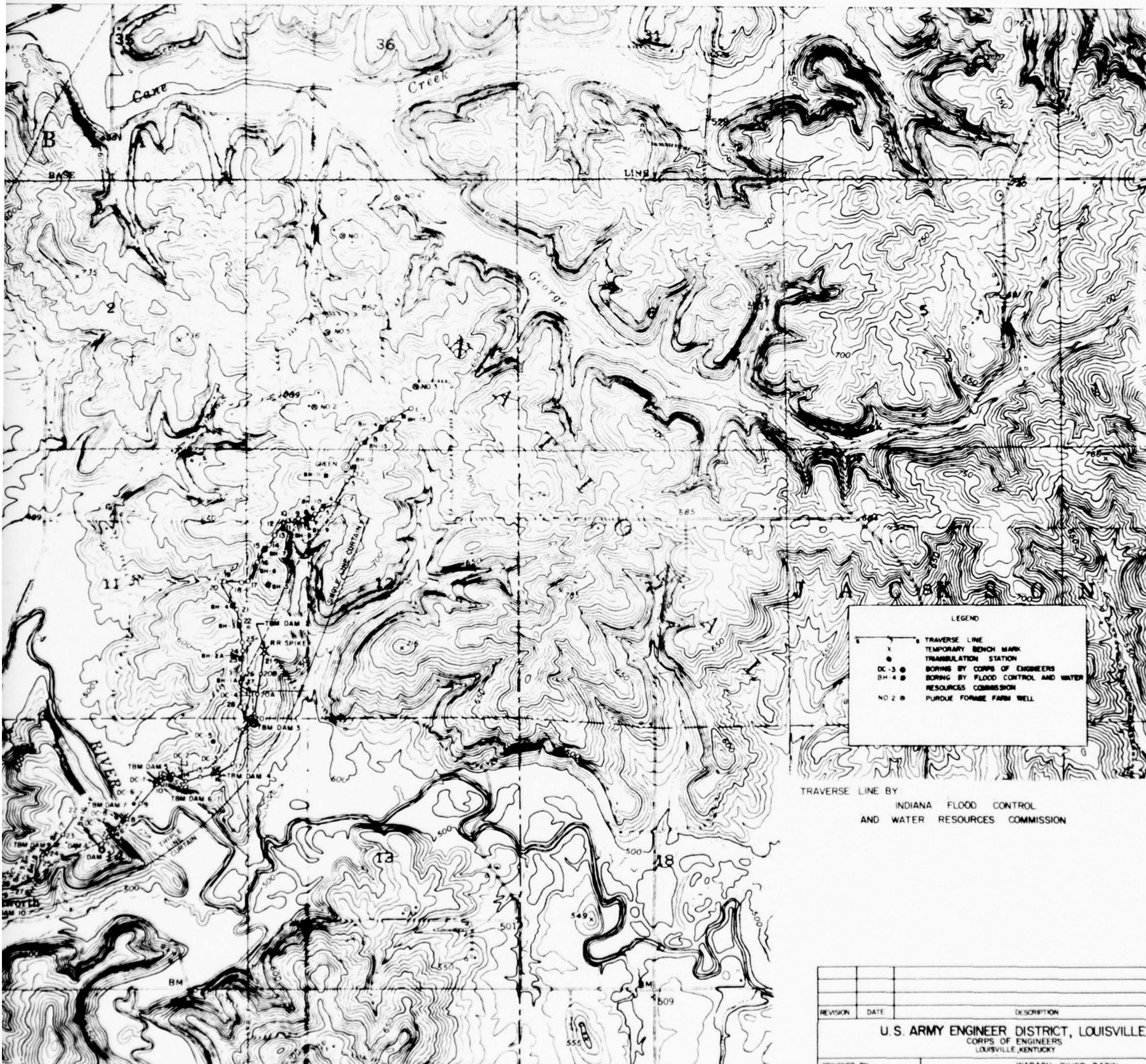
CORPS OF ENGINEERS

SCALE IN FEET

1000 0 1000 2000 3000

U.S. ARMY

2



TRAVERSE LINE BY
INDIANA FLOOD CONTROL
AND WATER RESOURCES COMMISSION

SCALE IN FEET
1000 0 1000 2000 3000

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

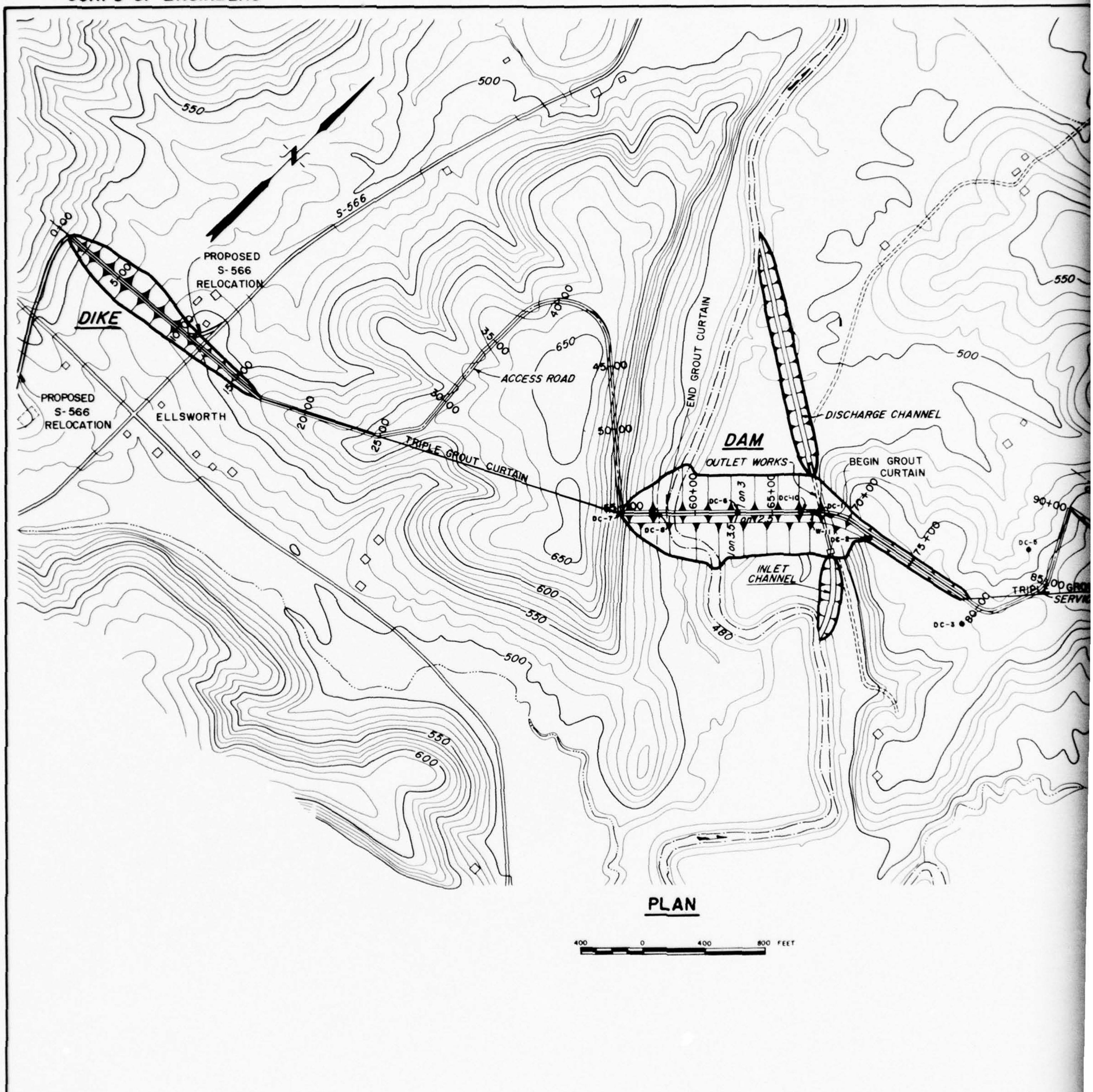
DESIGNED BY
DRAWN BY
TRACED BY
CHECKED BY
SUBMITTED
ASST. CHIEF, ENGINEERING DIV.
APPROVED
CHIEF, ENGINEERING DIVISION
APPROVED
DATE

WABASH RIVER BASIN
PATOKA RIVER RESERVOIR
PATOKA RIVER, ILLINOIS
LOCATION OF BORINGS

APPROVED DATE
COL., CORPS OF ENGINEERS, DISTRICT ENGINEER
SCALE
DRAWING NUMBER

PLATE E-22

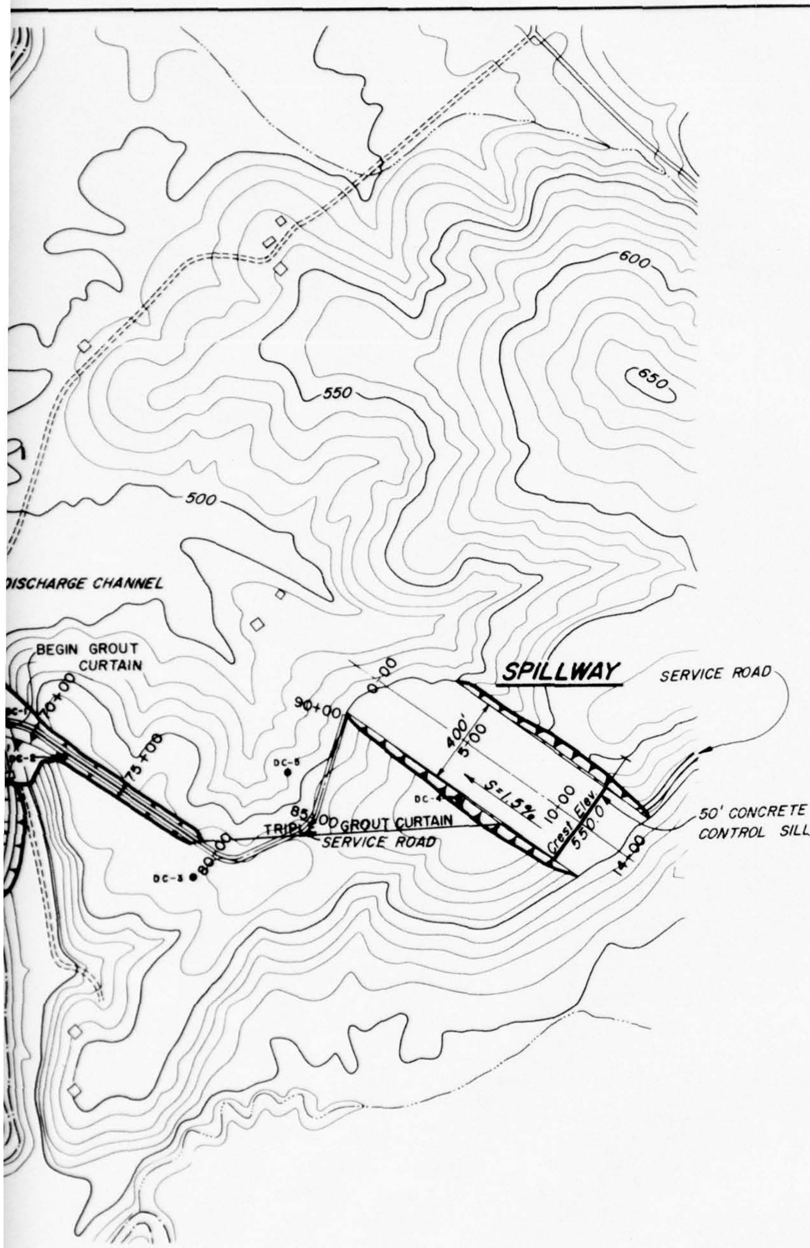
CORPS OF ENGINEERS



PLAN

400 0 400 800 FEET

2



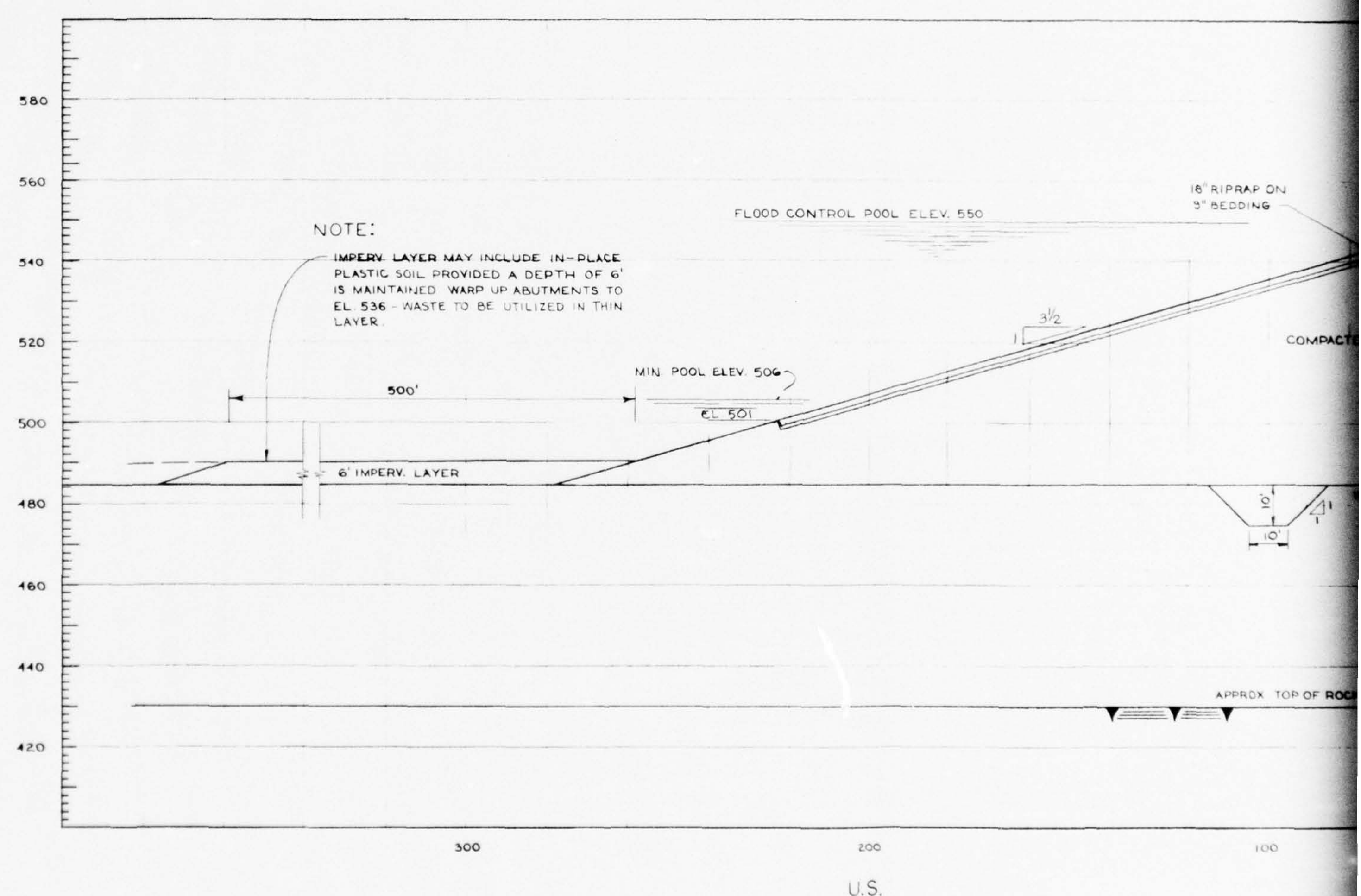
WABASH RIVER BASIN

PATOKA RESERVOIR

PATOKA RIVER, INDIANA

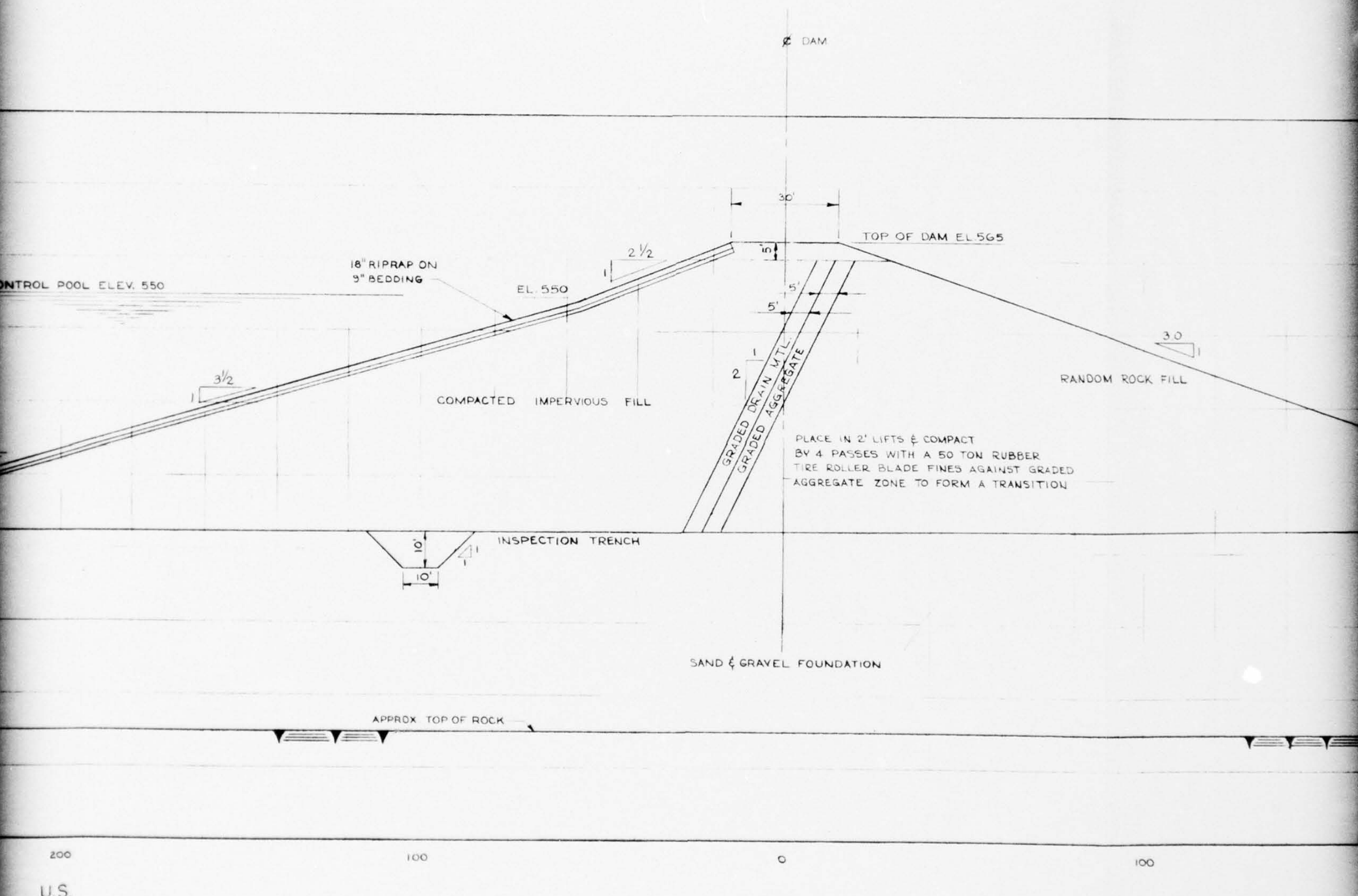
LOCATION OF BORINGS
DAM & SPILLWAY

DR. BY____ TR. BY____

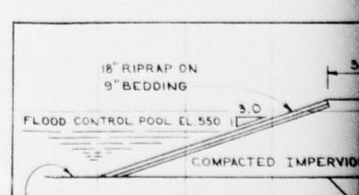


580
560
540
520
500
480
460
440
420
NOTE:
IMPERV. LAYER MAY INCLUDE IN-PLACE PLASTIC SOIL PROVIDED A DEPTH OF 6' IS MAINTAINED. WARP UP ABUTMENTS TO EL. 536 - WASTE TO BE UTILIZED IN THIN LAYER.
FLOOD CONTROL POOL ELEV. 550
18" RIPRAP ON 3" BEDDING
3½
1
COMPACTE
MIN. POOL ELEV. 506
EL. 501
500'
6' IMPERV. LAYER
10'
10'
1
APPROX. TOP OF ROC
300
200
100
U.S.

2



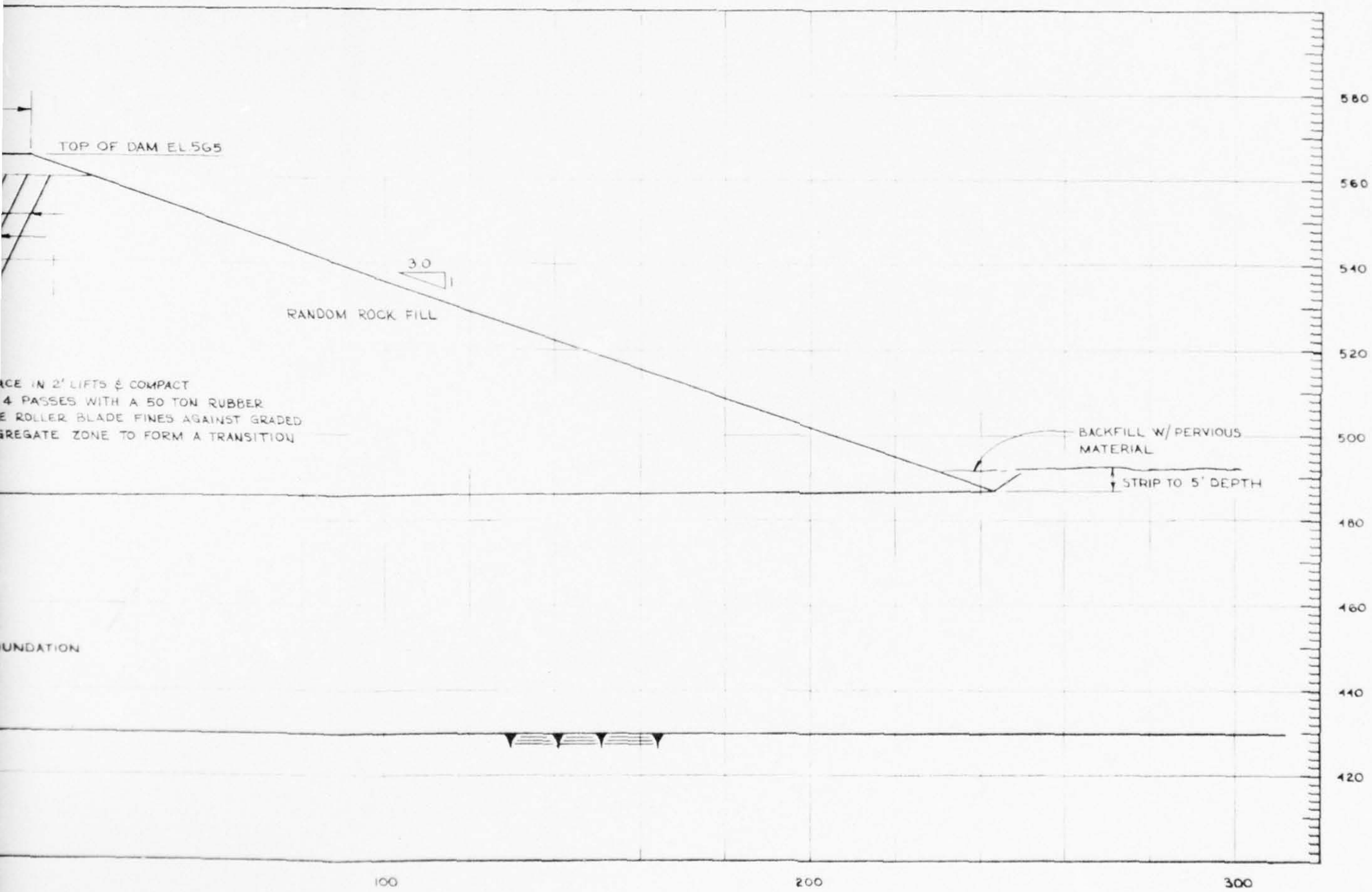
DAM
TYPICAL SECTION
SCALE: 1"=20' HOR & VERT.



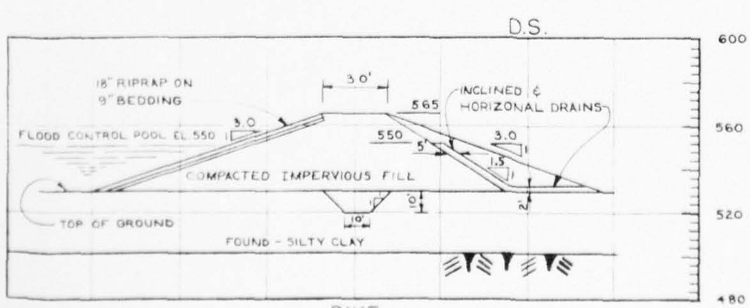
DI
TYPICAL
SCALE: 1"=4

3

AM



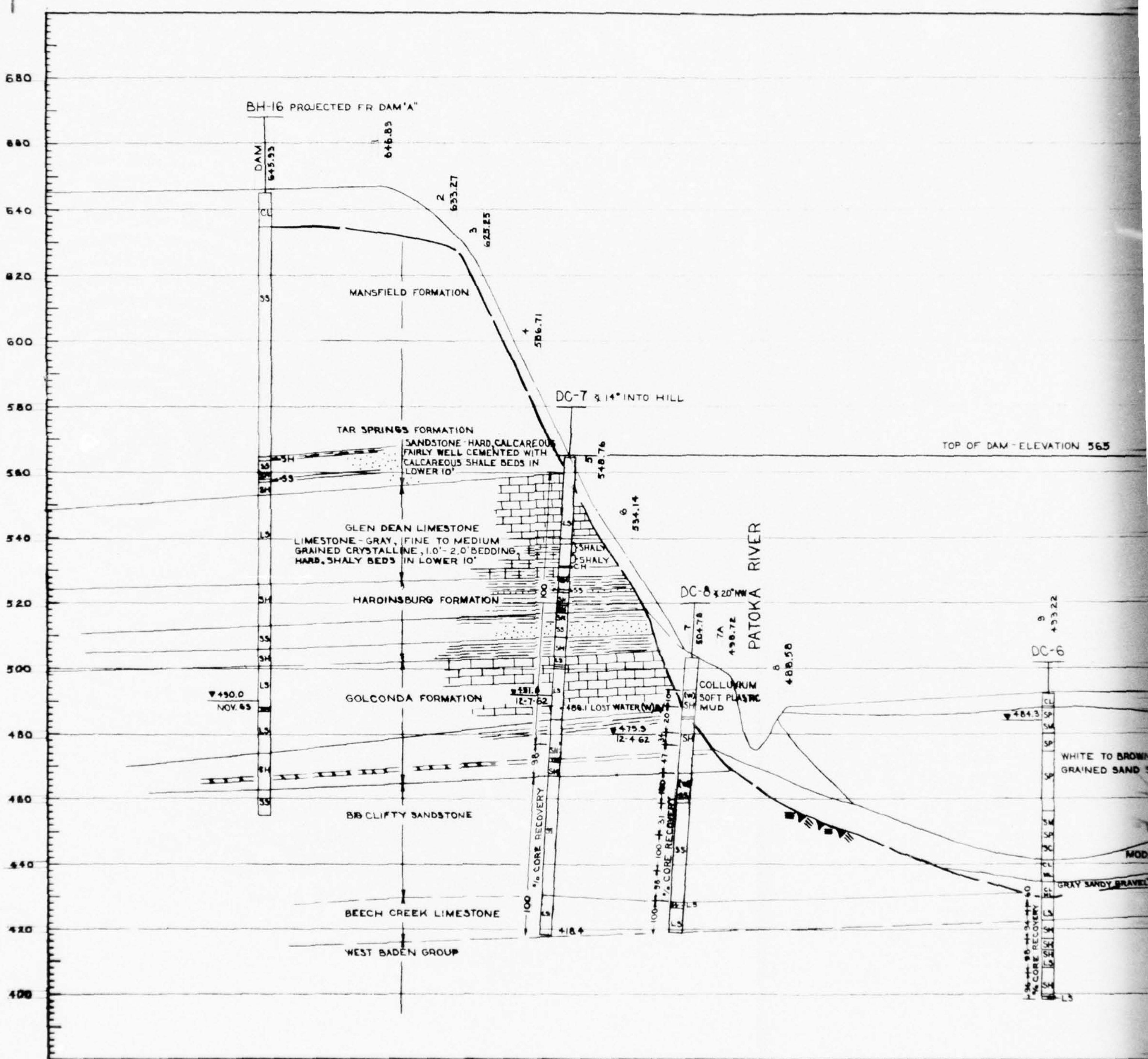
CTION
R & VERT.



DIKE
TYPICAL SECTION
SCALE: 1" = 40' HOR & VERT

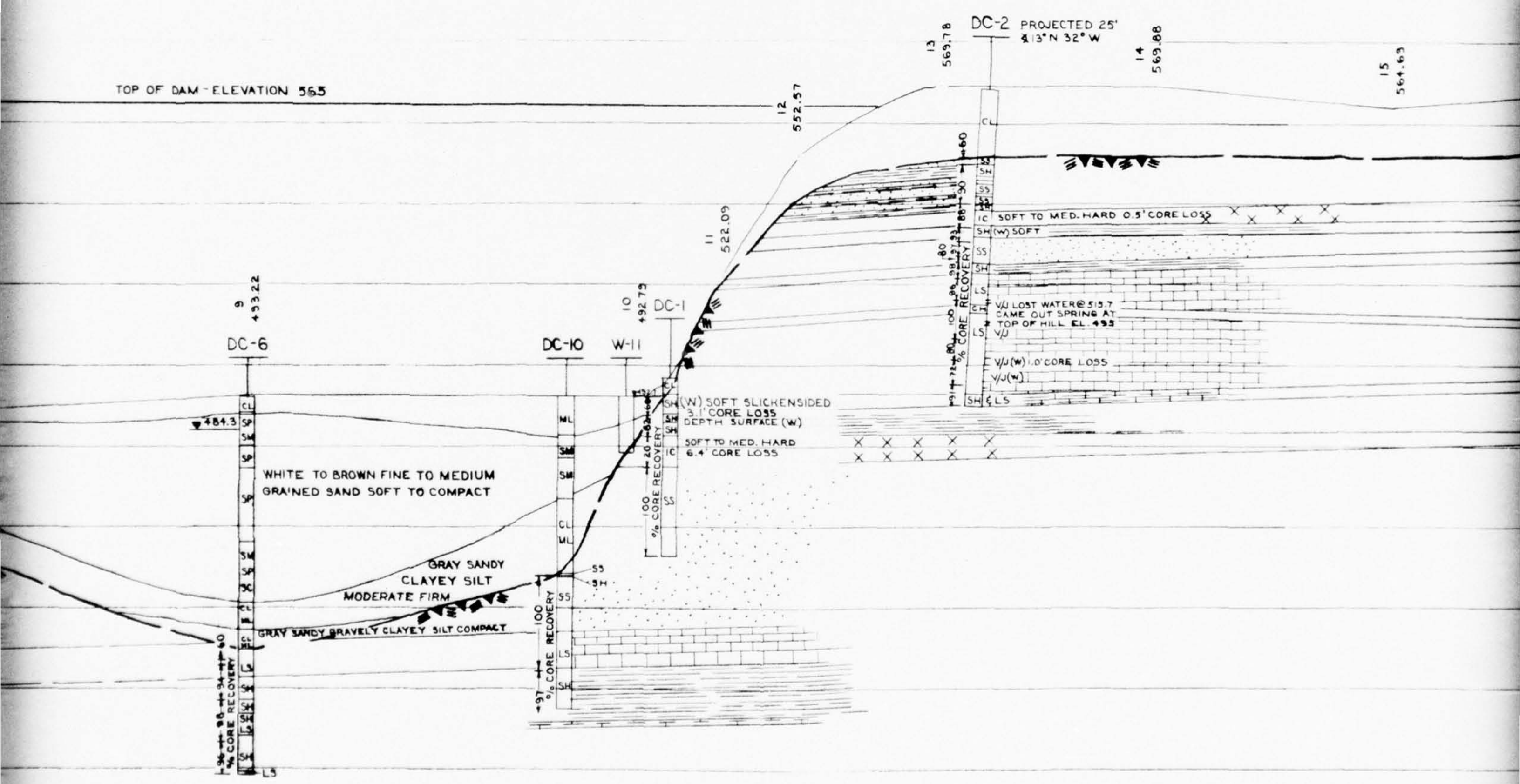
WABASH RIVER BASIN
PATOKA RESERVOIR
PATOKA RIVER, INDIANA
SECTION OF DAM
DR. BY C.M.M.   TR. BY JW

PLATE E-24



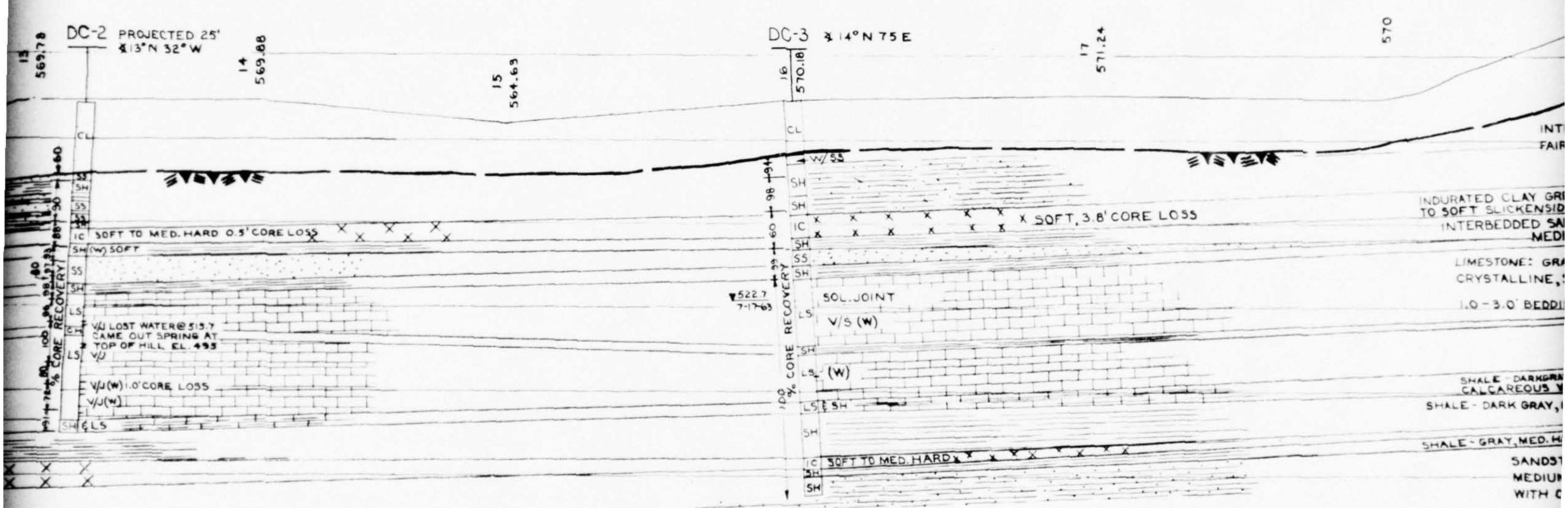
680
660
640
620
600
580
560
540
520
500
480
460
440
420
400
BH-16 PROJECTED FR DAM 'A"
DAM 645.93
646.83
2 633.27
3 625.25
MANSFIELD FORMATION
4 586.71
DC-7 & 14° INTO HILL
TAR SPRINGS FORMATION
SANDSTONE - HARD, CALCAREOUS FAIRLY WELL CEMENTED WITH CALCAREOUS SHALE BEDS IN LOWER 10'
TOP OF DAM - ELEVATION 565
5 548.76
6 534.14
GLEN DEAN LIMESTONE
LIMESTONE - GRAY, FINE TO MEDIUM GRAINED CRYSTALLINE, 1.0' - 2.0' BEDDING, HARD, SHALY BEDS IN LOWER 10'
PATOKA RIVER
HARDINSBURG FORMATION
DC-8 & 20° NW
7 504.78
7A 498.72
8 488.58
9 493.22
DC-6
COLLUVIUM SOFT PLASTIC MUD
GOLCONDA FORMATION
490.0 NOV. 63
481.6 12-7-62
488.1 LOST WATER
475.9 12-4-62
484.3
WHITE TO BROWN GRAINED SAND
BIG CLIFTY SANDSTONE
% CORE RECOVERY
GRAY SANDY GRAVEL
BEECH CREEK LIMESTONE
418.4
WEST BADEN GROUP

2

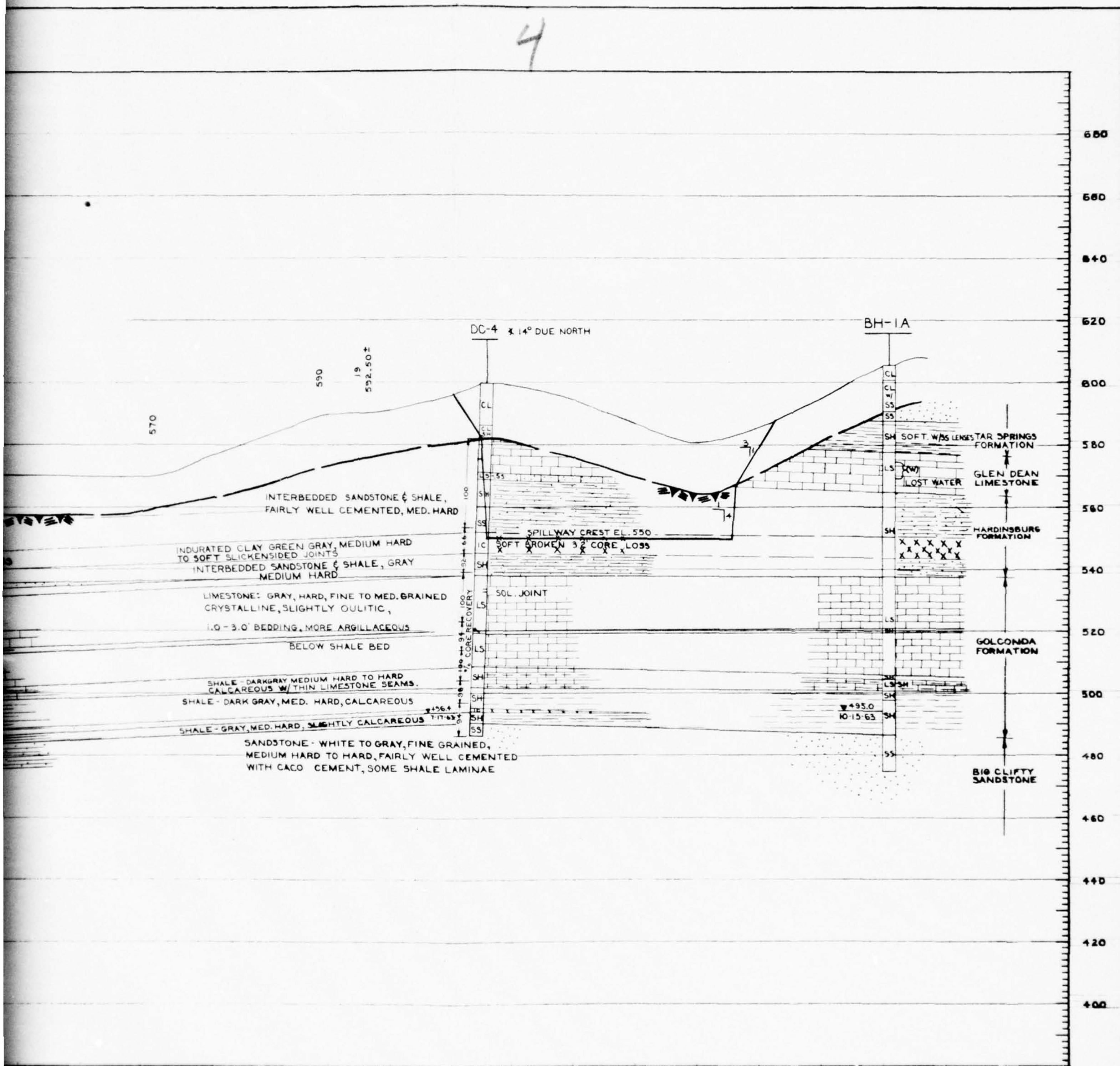


SCALE: 1" = 20' VERT.
1" = 100' HORIZ.

3



SCALE: 1" = 20' VERT.
1" = 100' HORIZ.



WABASH RIVER BASIN

PATOKA RESERVOIR

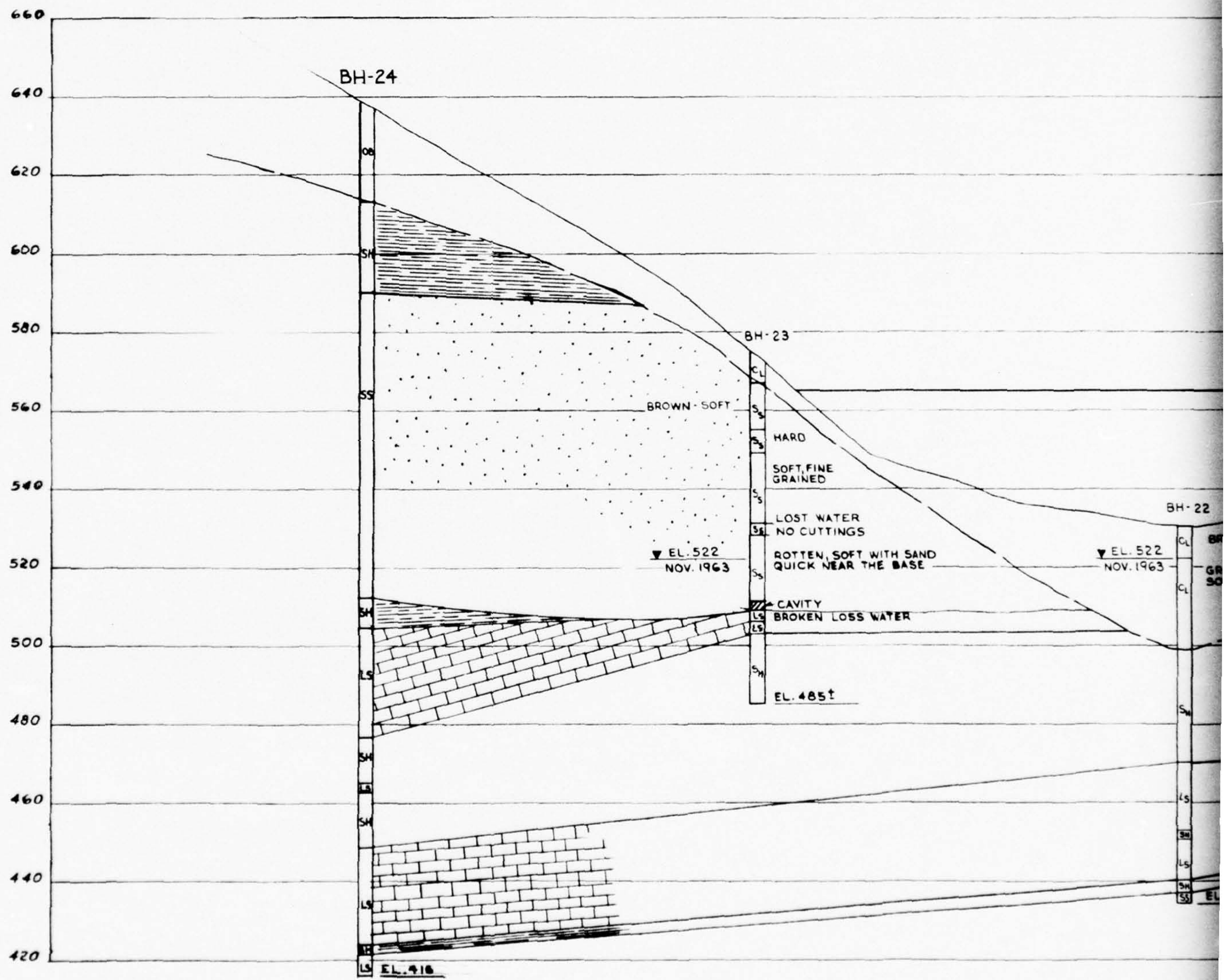
PATOKA RIVER, INDIANA

GEOLOGIC PROFILE

DAM & ABUTMENTS

DR. BY H.E.T. TR BY

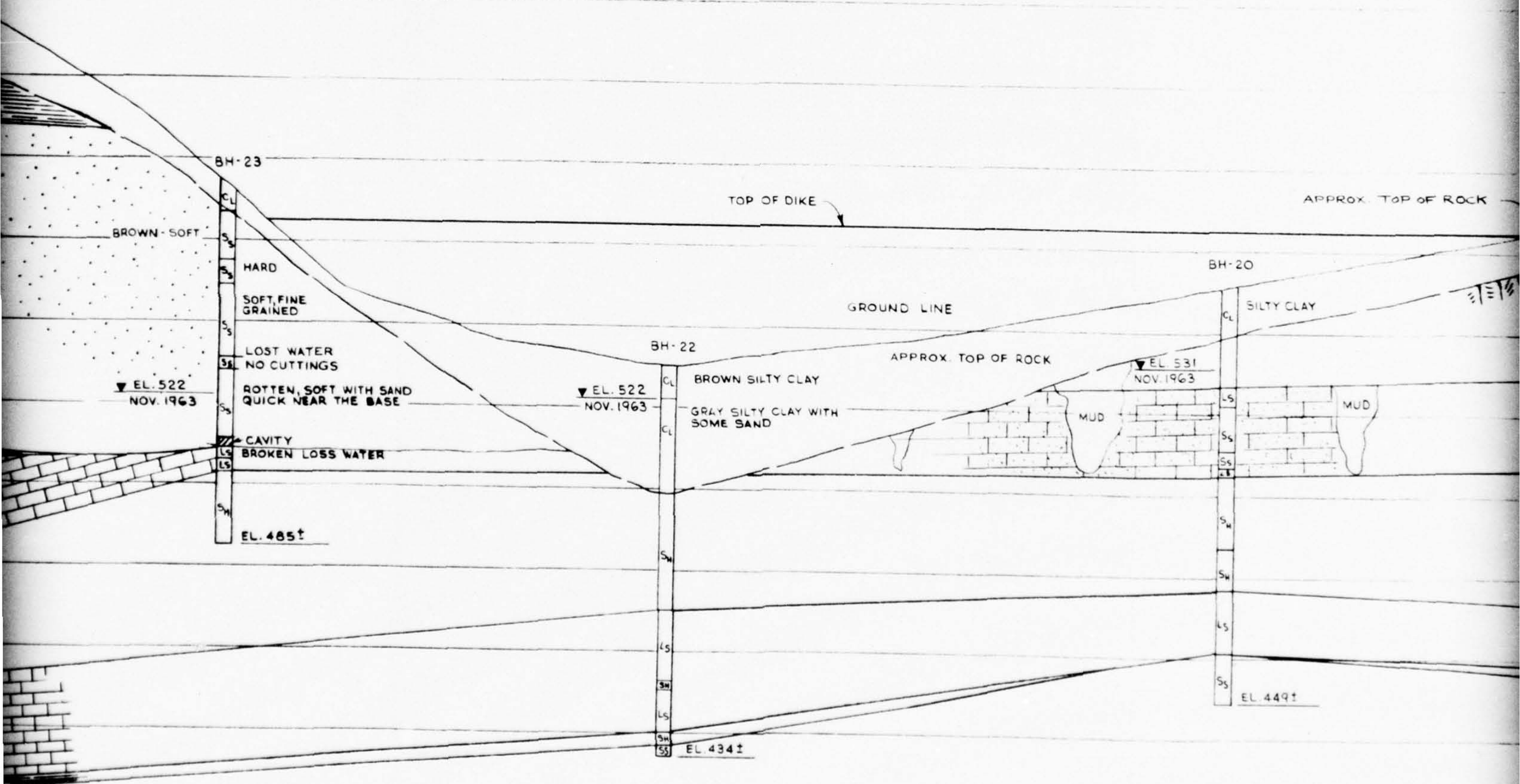
PLATE E-25



NOTE:

ELEVATIONS AND LOCATIONS OF HOLES BH-16 THROUGH BH-24 ARE APPROXIMATE. THEY HAVE BEEN ESTIMATED FROM TOPOGRAPHIC MAP.

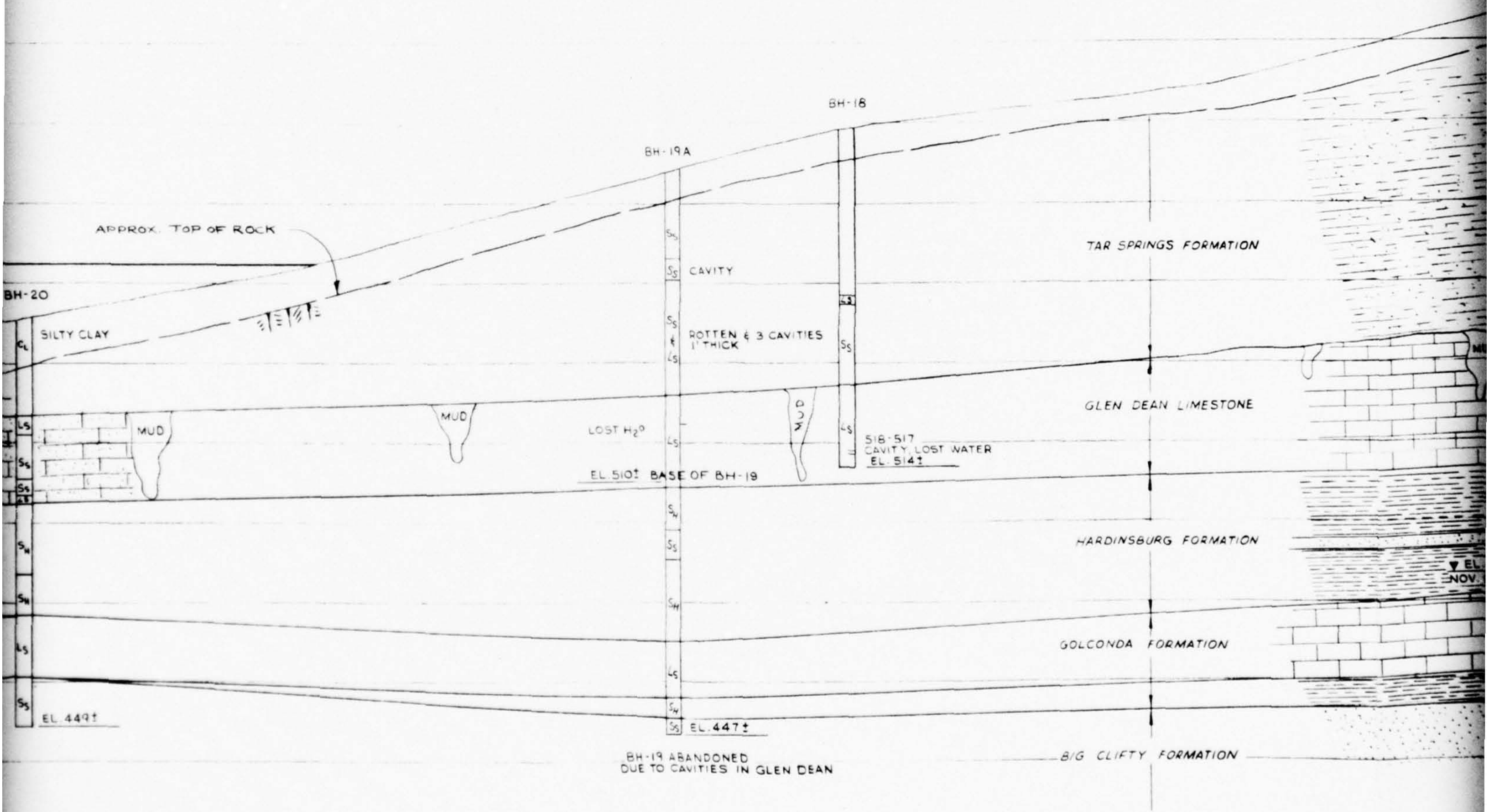
2



OCATIONS OF HOLES BH-16
OXIMATE. THEY HAVE BEEN
APHIC MAP.

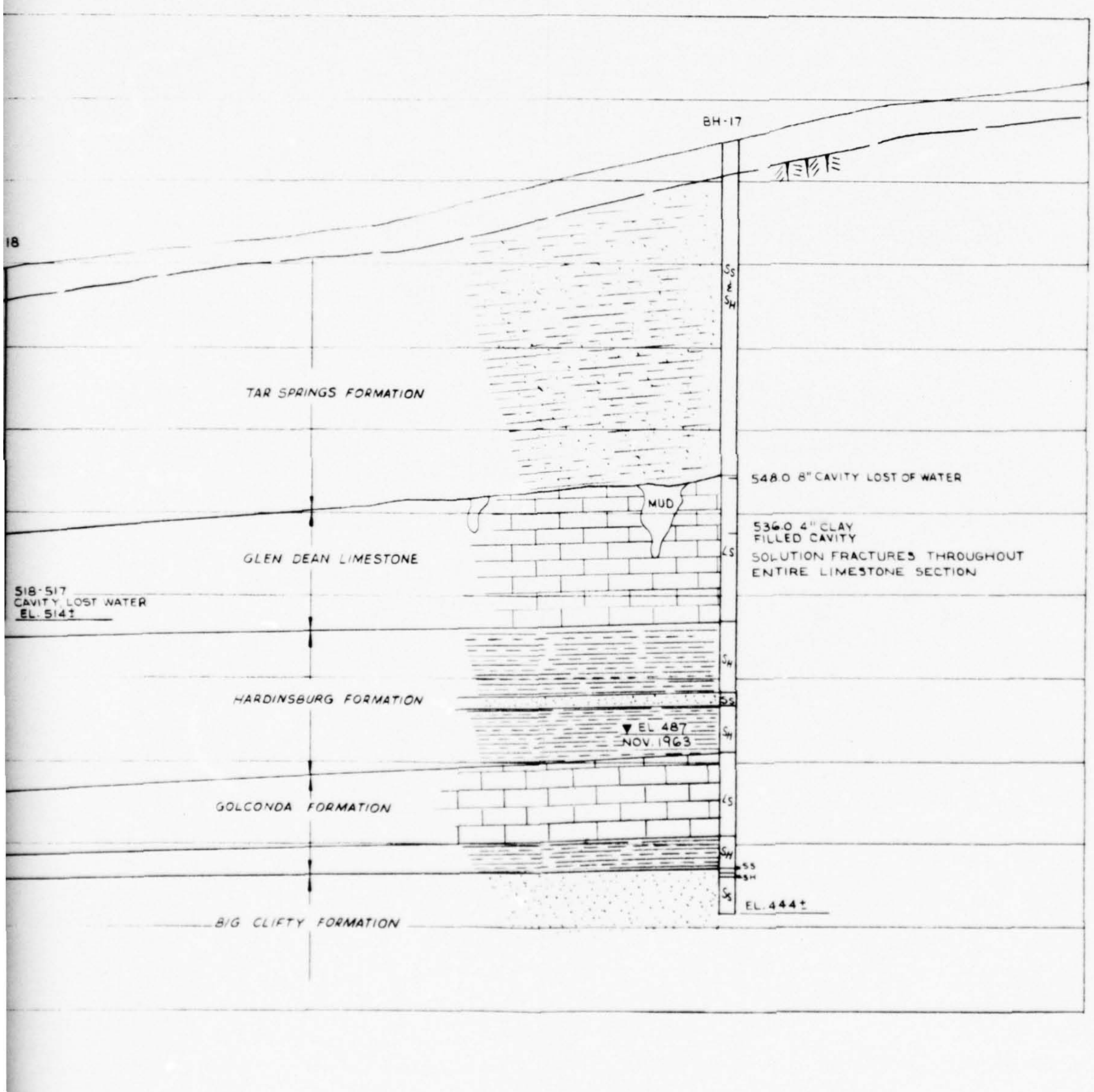
SCALES: 1" = 20' VERT.
1" = 100' HORIZ.

3



: 1" = 20' VERT.
1" = 100' HORIZ.

4



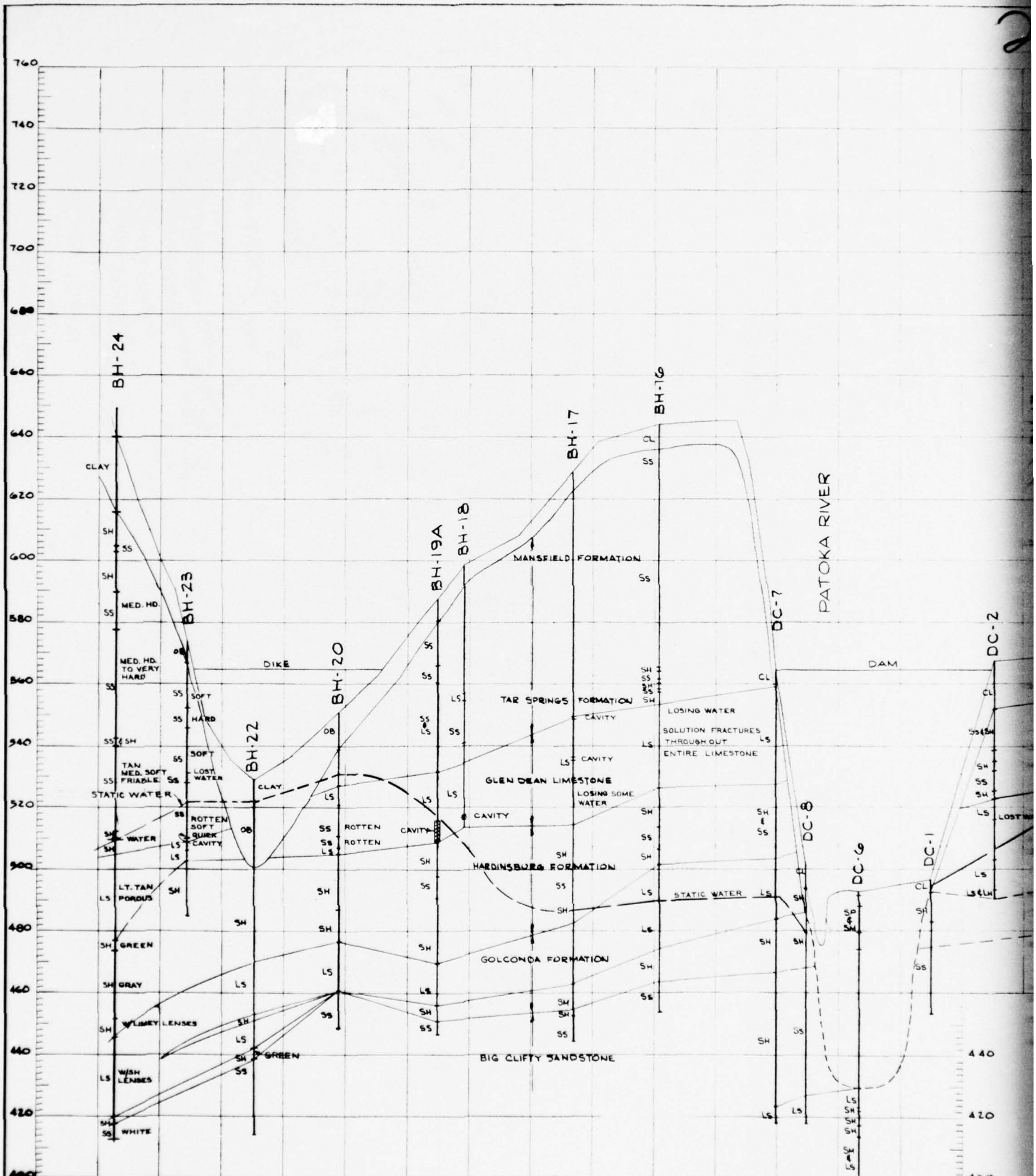
WABASH RIVER BASIN
PATOKA RESERVOIR
PATOKA RIVER, INDIANA

GEOLOGIC PROFILE OF DIKE

DR. BY H.E.T. TR. BY. C.T.B.

PLATE E-26

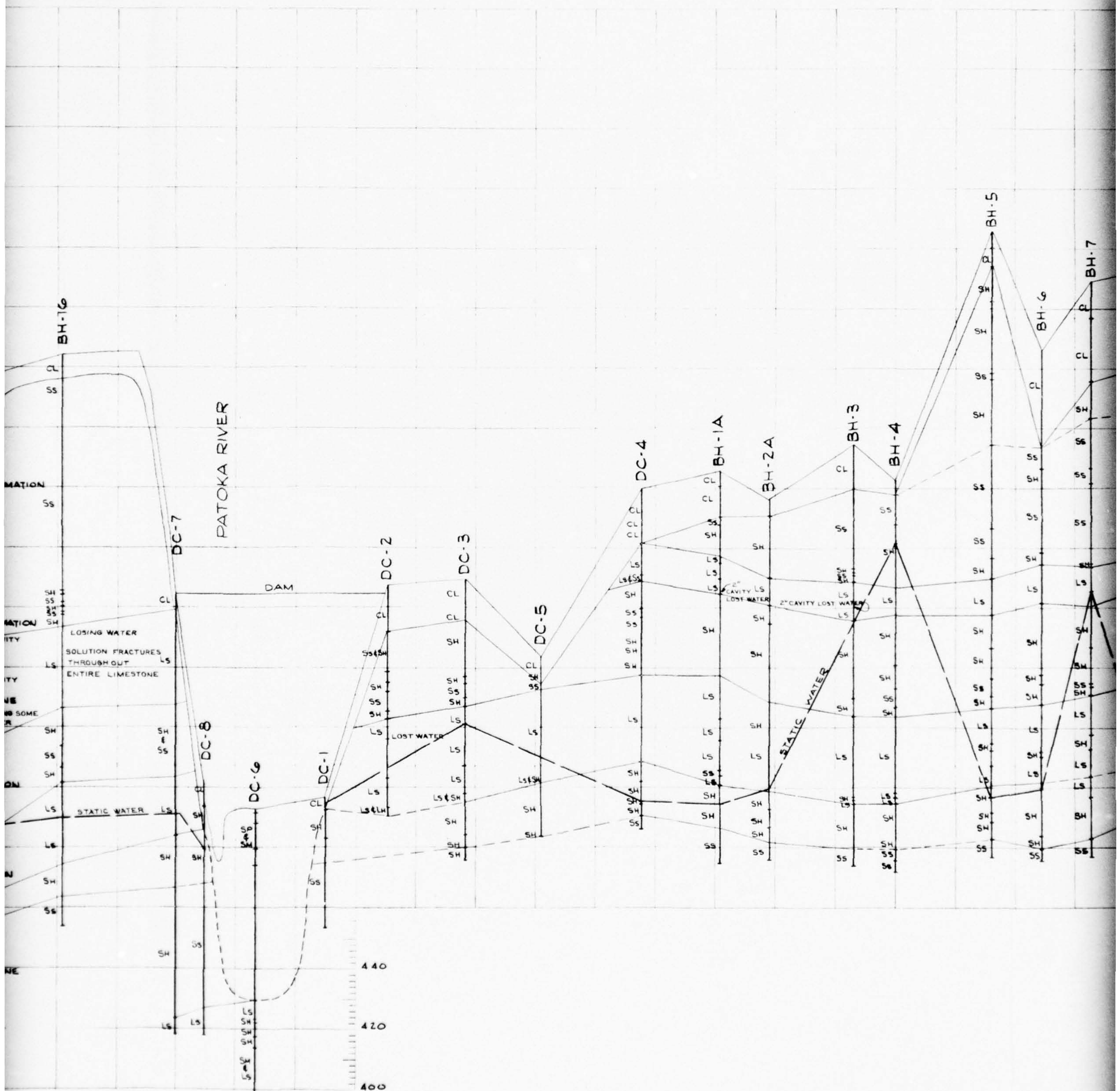
1



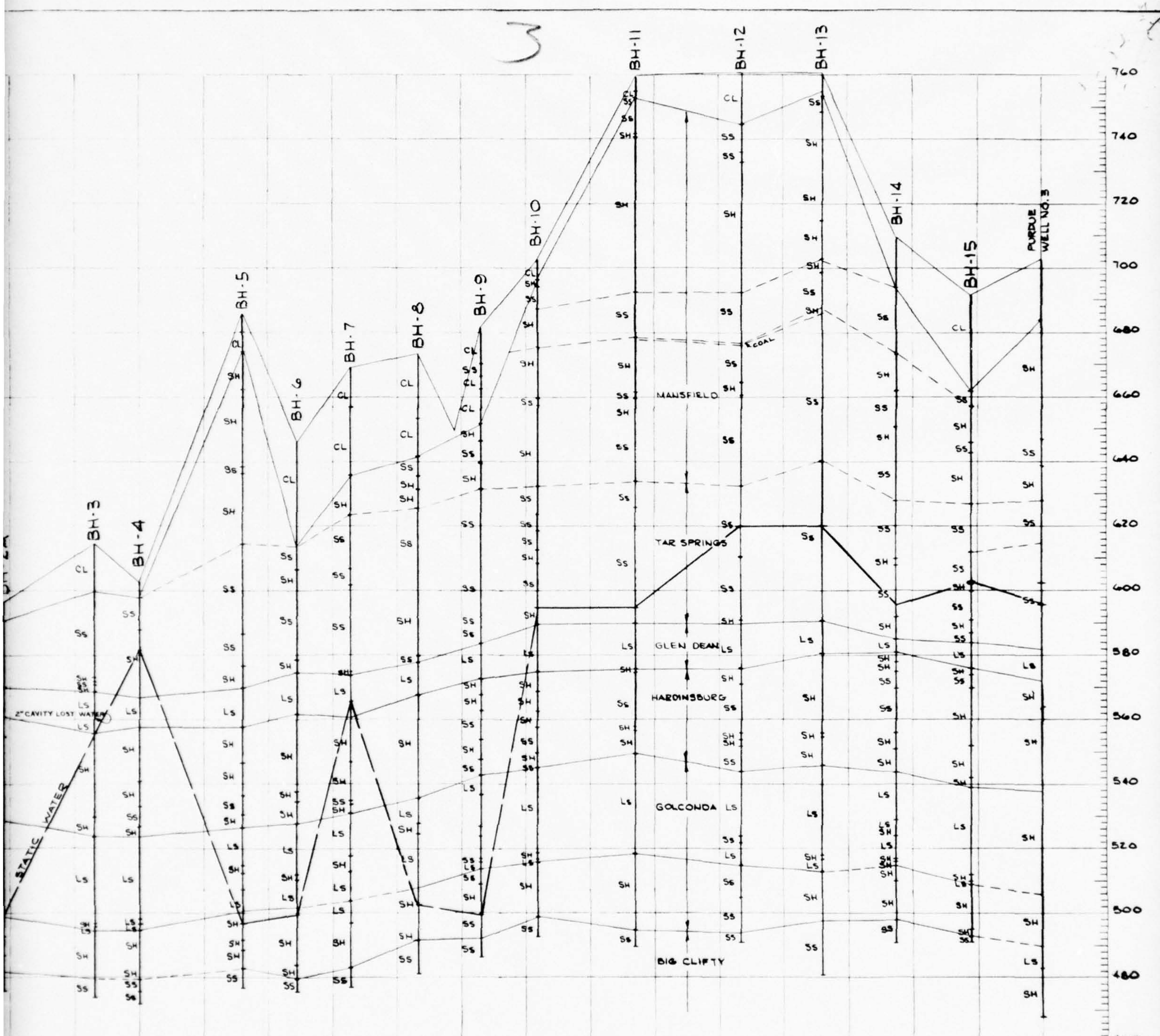
760
740
720
700
680
660
640
620
600
580
560
540
520
500
480
460
440
420
400
BH-24
BH-23
BH-22
BH-20
BH-19A
BH-18
BH-17
BH-16
DC-7
DC-8
DC-9
DC-1
DC-2
PATOKA RIVER
DIKE
DAM
CLAY
MED. HD.
MED. HD. TO VERY HARD
TAN MED. SOFT FRIABLE
STATIC WATER
WATER
LT. TAN POROUS
GREEN
GRAY
W/LIMEY LENSES
W/SH LENSES
WHITE
SOFT
HARD
LOST WATER
ROTTEN
SOFT QUICK
CAVITY
MANSFIELD FORMATION
TAR SPRINGS FORMATION
GLEN DEAN LIMESTONE
LOSING SOME WATER
HARDINSBURG FORMATION
GOLCONDA FORMATION
BIG CLIFTY SANDSTONE
LOSING WATER
SOLUTION FRACTURES THROUGH OUT ENTIRE LIMESTONE
STATIC WATER

2

2



BH-16
DC-7
PATOKA RIVER
DC-8
DC-9
DC-1
DC-2
DC-3
DC-5
DC-4
BH-1A
BH-2A
BH-3
BH-4
BH-5
BH-6
BH-7
DAM
LOSING WATER
SOLUTION FRACTURES THROUGH OUT ENTIRE LIMESTONE
STATIC WATER
LOST WATER
2" CAVITY LOST WATER
440
420
400



WABASH RIVER BASIN

PATOKA RESERVOIR

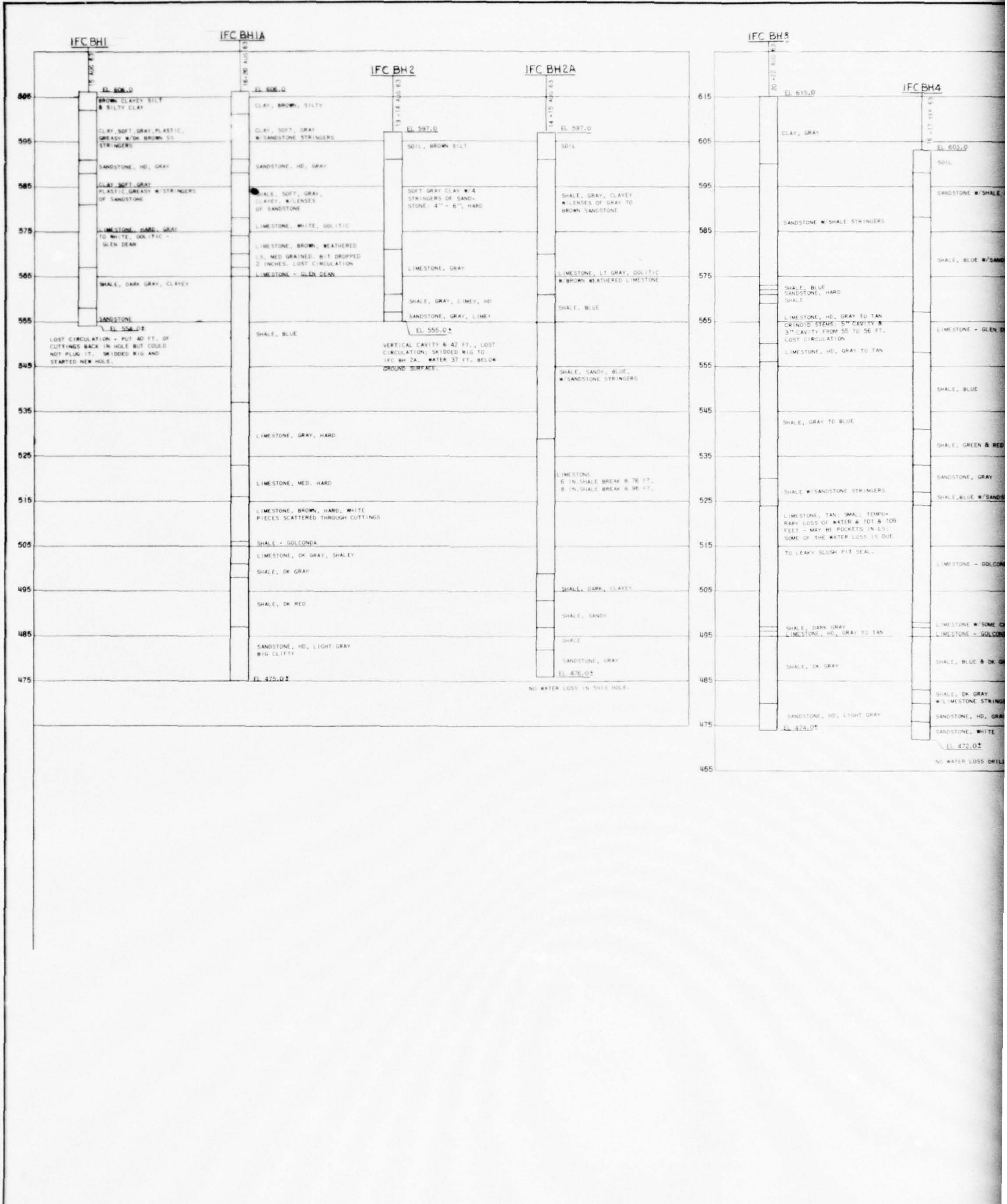
PATOKA RIVER, INDIANA

GEOLOGIC PROFILE
AND GROUND WATER STUDY

DR. BY: C.M.M. TR. BY: W.L.B.

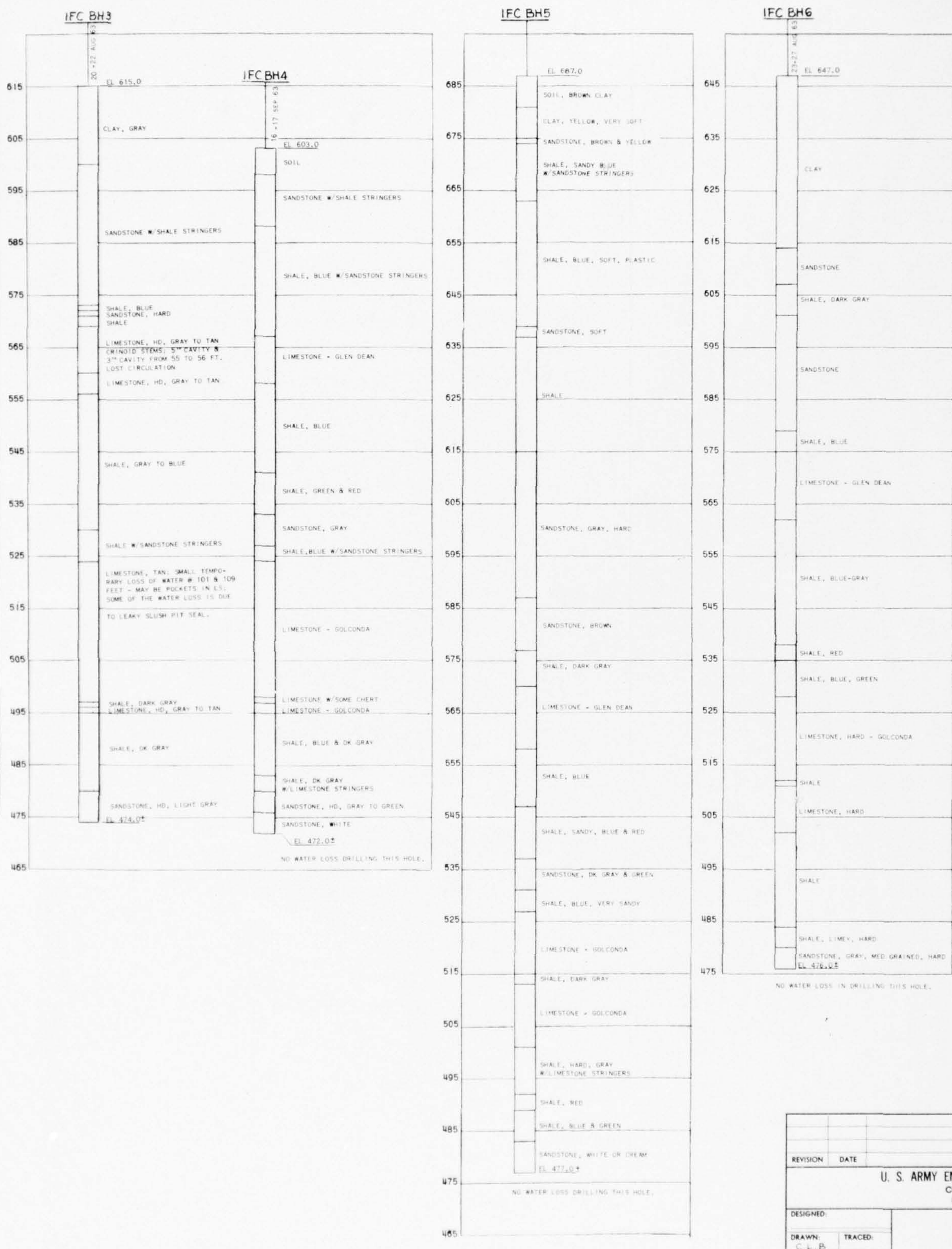
PLATE E-27

CORPS OF ENGINEERS



U.S. ARMY

2



REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

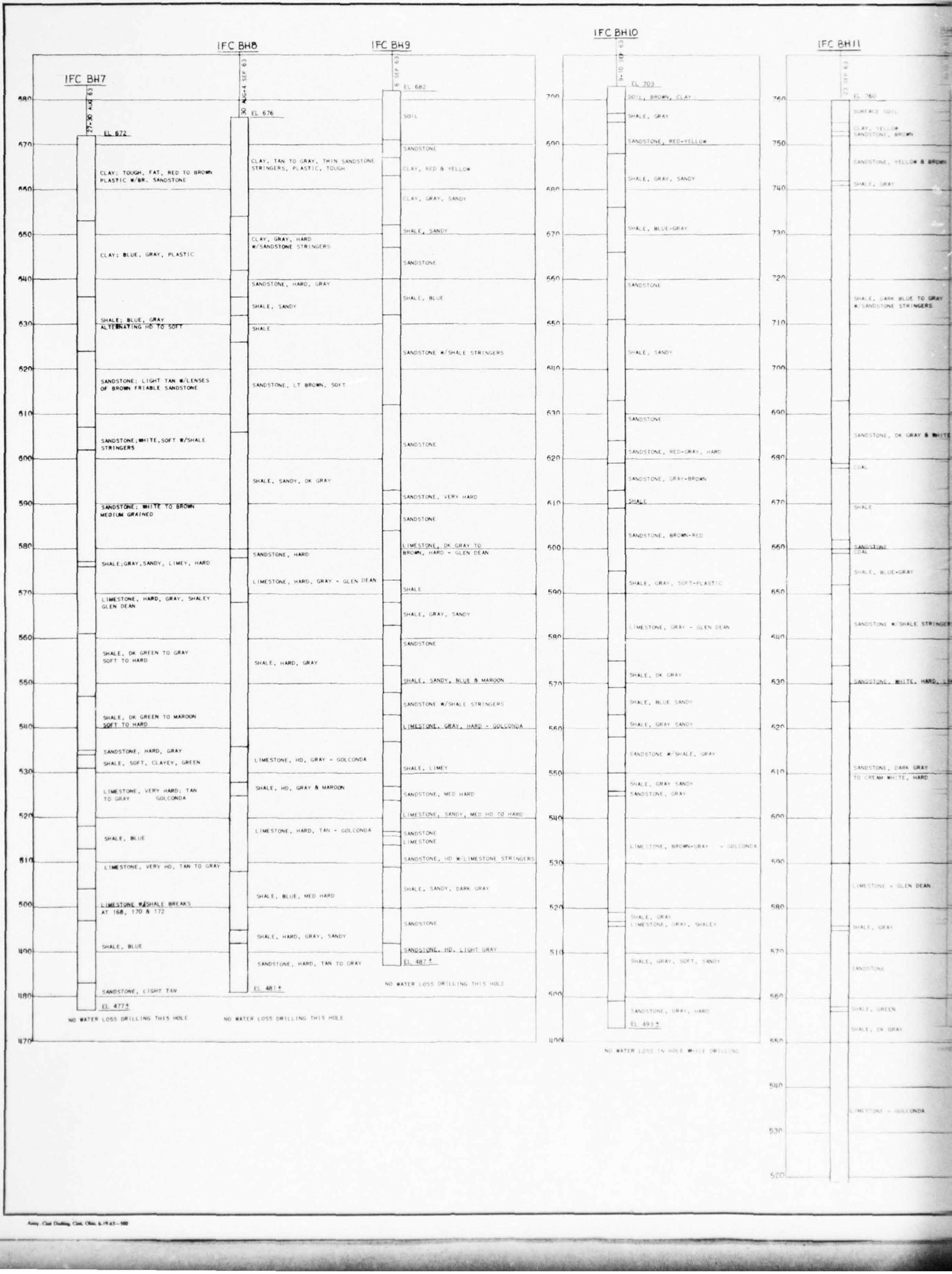
WABASH RIVER BASIN
PATOKA RIVER RESERVOIR
PATOKA RIVER, ILLINOIS

BORING LOGS
SHEET 1

DESIGNED:	
DRAWN: C.L.B	TRACED:
CHECKED: J.W.R.	HET
SUBMITTED:	
APPROVAL RECM:	APPROVED: DATE:
ASST. CHIEF ENGINEERING DIV	COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
APPROVED:	SCALE:
CHIEF, ENGINEERING DIVISION	DRAWING NUMBER

PLATE E-28

CORPS OF ENGINEERS



U.S. ARMY

2

REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

DESIGNED:

DRAWN: C. L. B. TRACED:

CHECKED: J. W. R.

SUBMITTED:

WABASH RIVER BASIN
PATOKA RIVER RESERVOIR
PATOKA RIVER, ILLINOIS

BORING LOGS
SHEET 2

APPROVAL RECM: APPROVED: DATE:

ASST. CHIEF ENGINEERING DIV. COL., CORPS OF ENGINEERS, DISTRICT ENGINEER

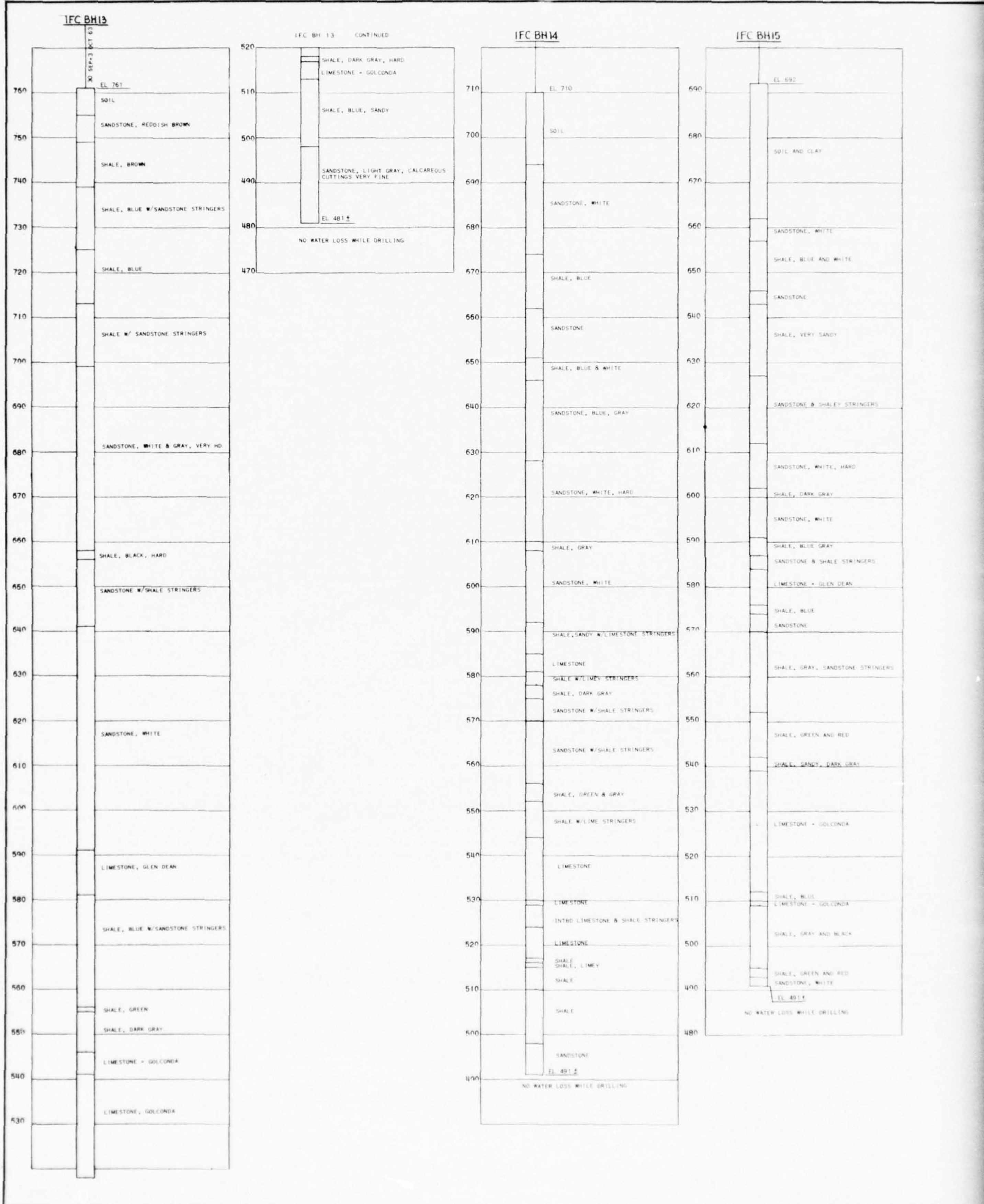
APPROVED: SCALE:

DRAWING NUMBER

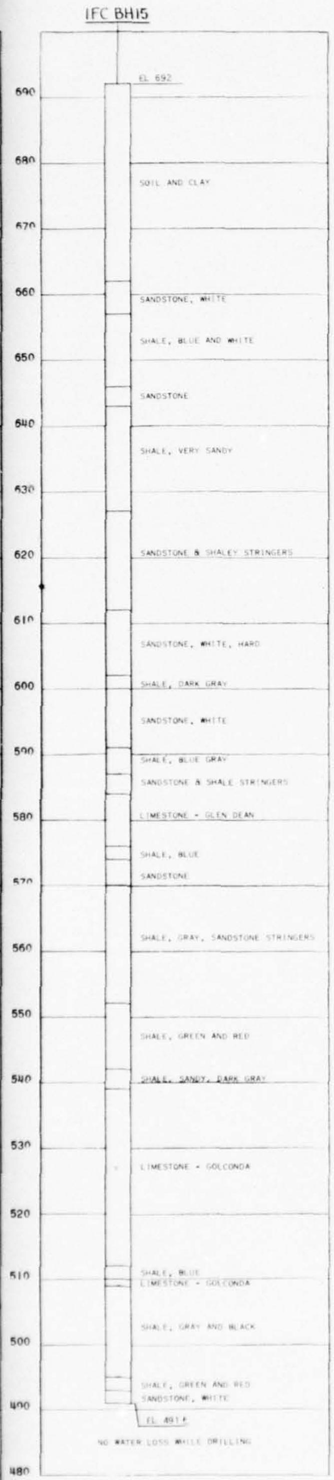
CHIEF, ENGINEERING DIVISION

PLATE E-29

CORPS OF ENGINEERS



U.S. ARMY



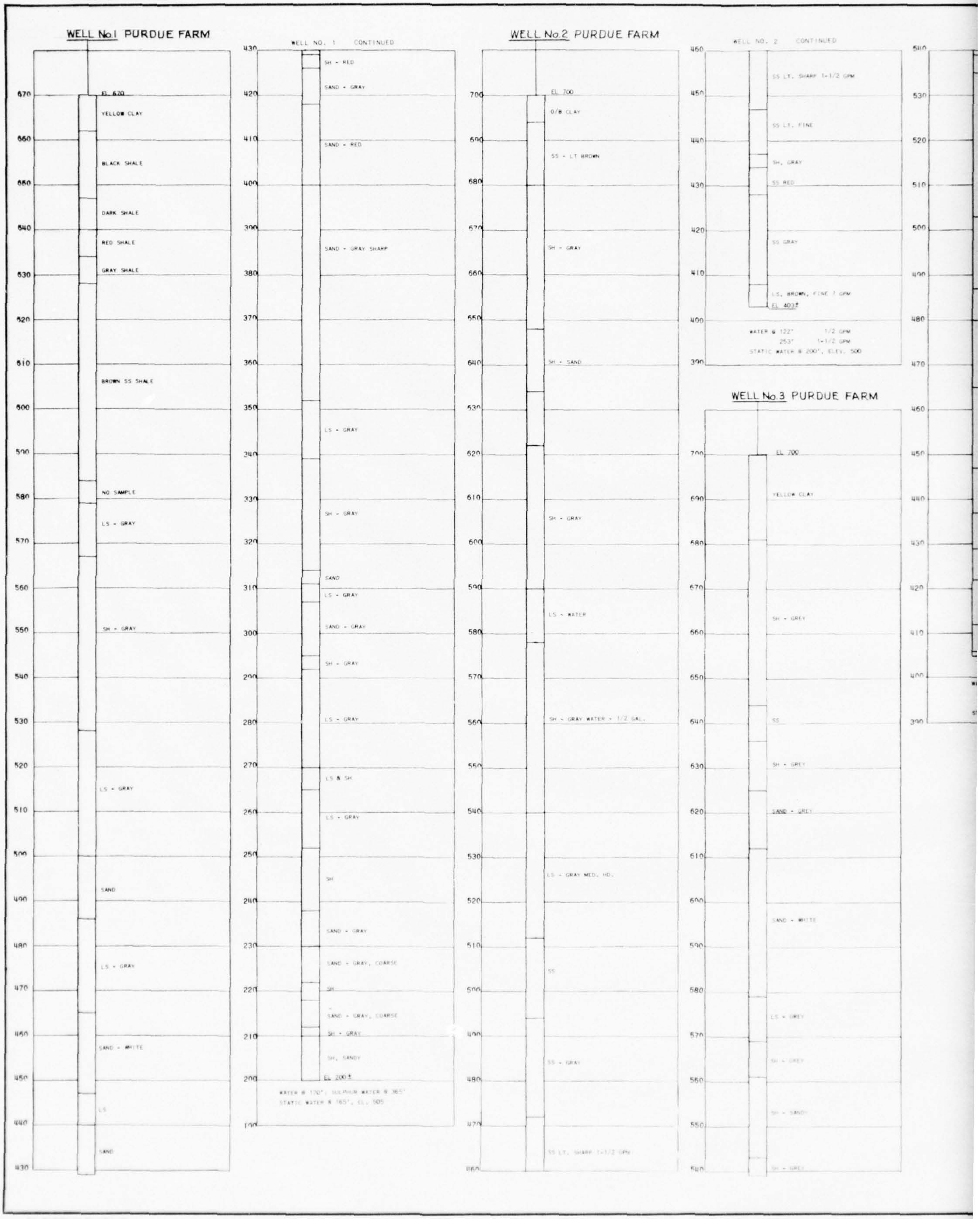
REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

DESIGNED:	WABASH RIVER BASIN
DRAWN: C.L.B. TRACED:	PATOKA RIVER RESERVOIR
CHECKED: J.W.R.	PATOKA RIVER, ILLINOIS
SUBMITTED:	BORING LOGS SHEET 3
APPROVAL RECM: ASST. CHIEF ENGINEERING DIV	APPROVED: COL. CORPS OF ENGINEERS, DISTRICT ENGINEER DATE:
APPROVED: CHIEF, ENGINEERING DIVISION	SCALE: DRAWING NUMBER

PLATE E-30

CORPS OF ENGINEERS



U.S. ARMY

REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

DESIGNED:
DRAWN: C. L. B. TRACED:
CHECKED: J. W. R. HLT
SUBMITTED:

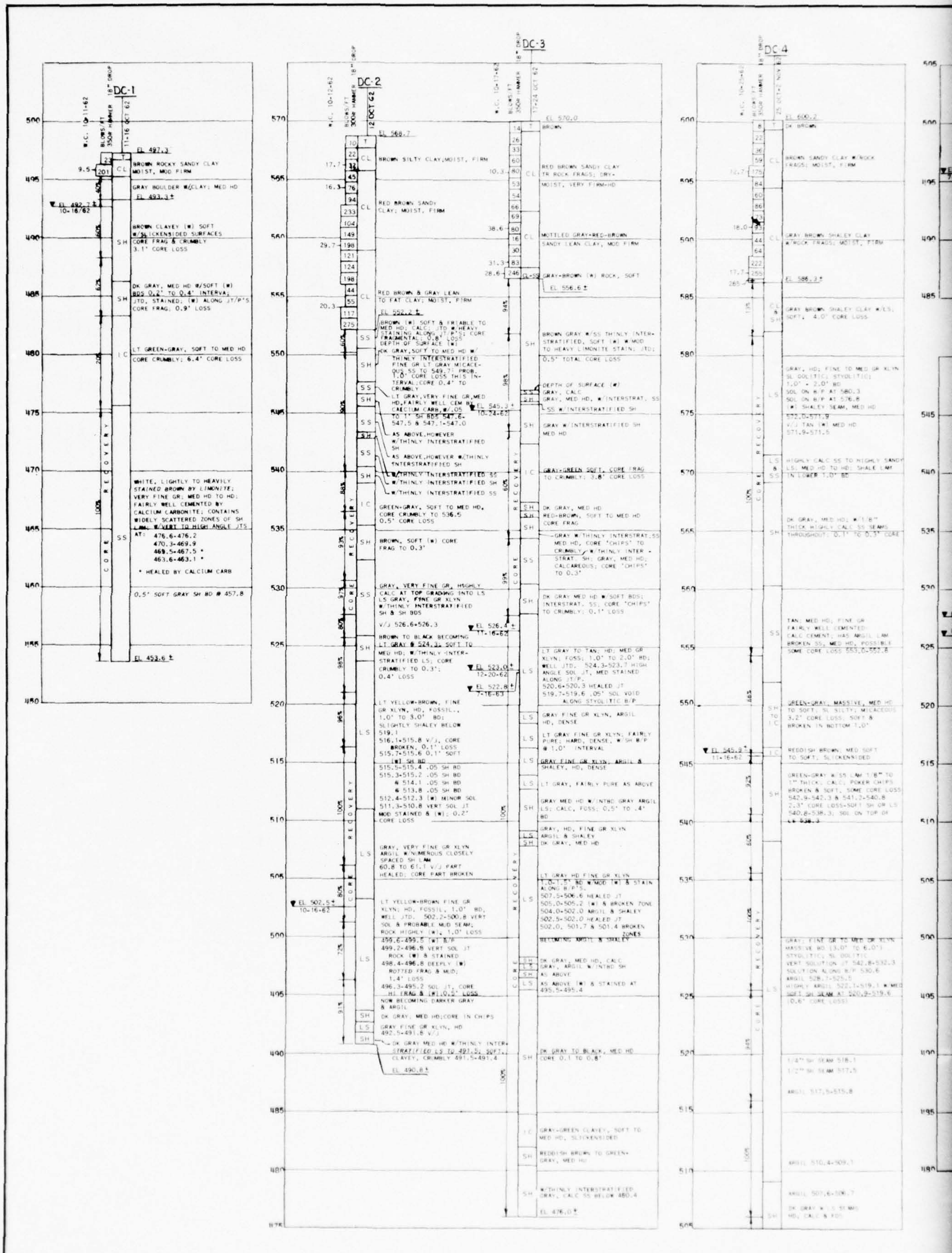
WABASH RIVER BASIN
PATOKA RIVER RESERVOIR
PATOKA RIVER, ILLINOIS

BORING LOGS
SHEET 4

APPROVAL RECM: APPROVED: DATE:
ASST. CHIEF ENGINEERING DIV. COL. CORPS OF ENGINEERS DISTRICT ENGINEER
APPROVED: SCALE:
DRAWING NUMBER
CHIEF, ENGINEERING DIVISION

PLATE E-31

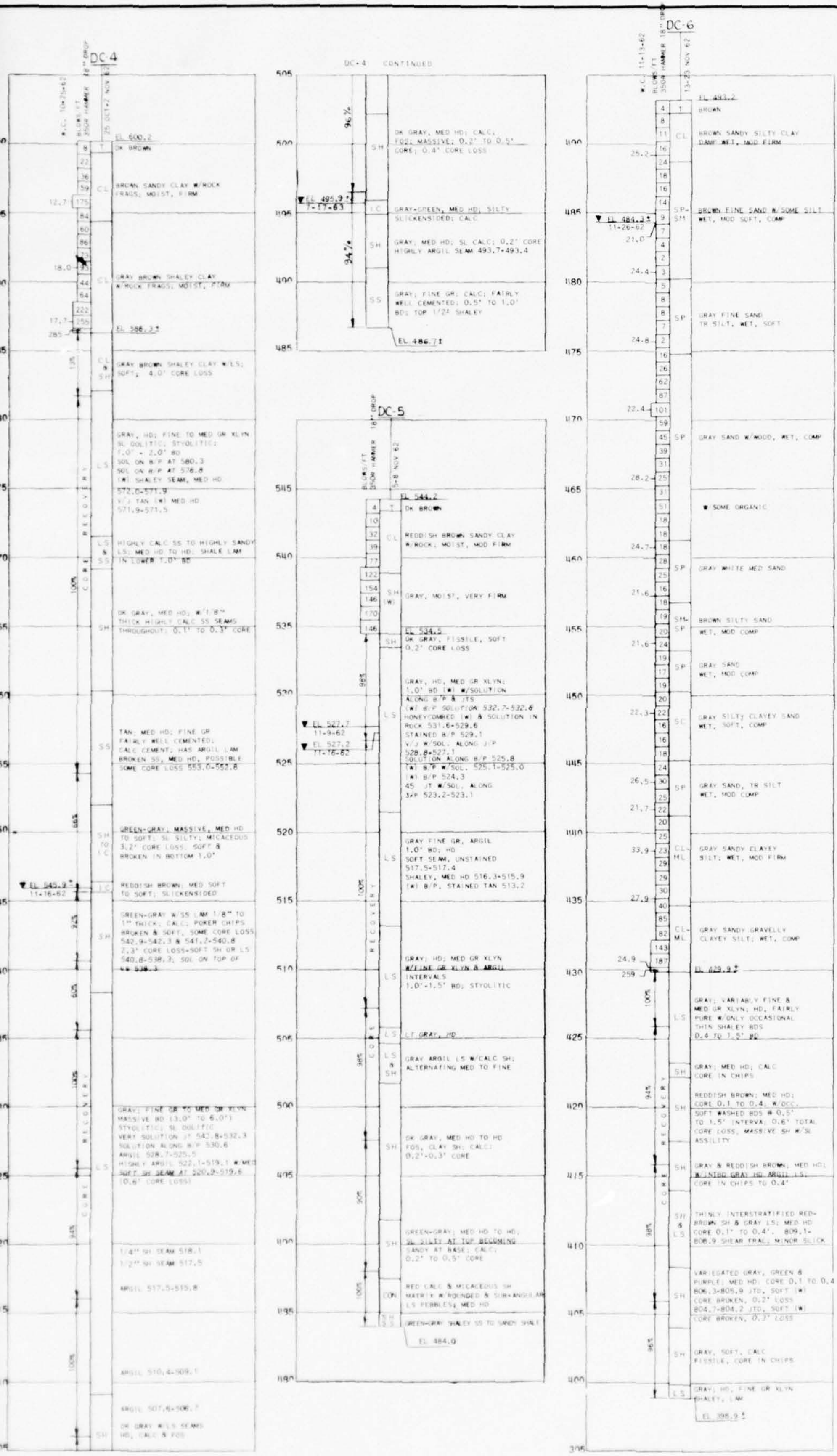
CORPS OF ENGINEERS



Army-Cinti Drafting, Cinti, Ohio, 6.19.63-500

U.S. ARMY

2



REVISION	DATE	DESCRIPTION	BY

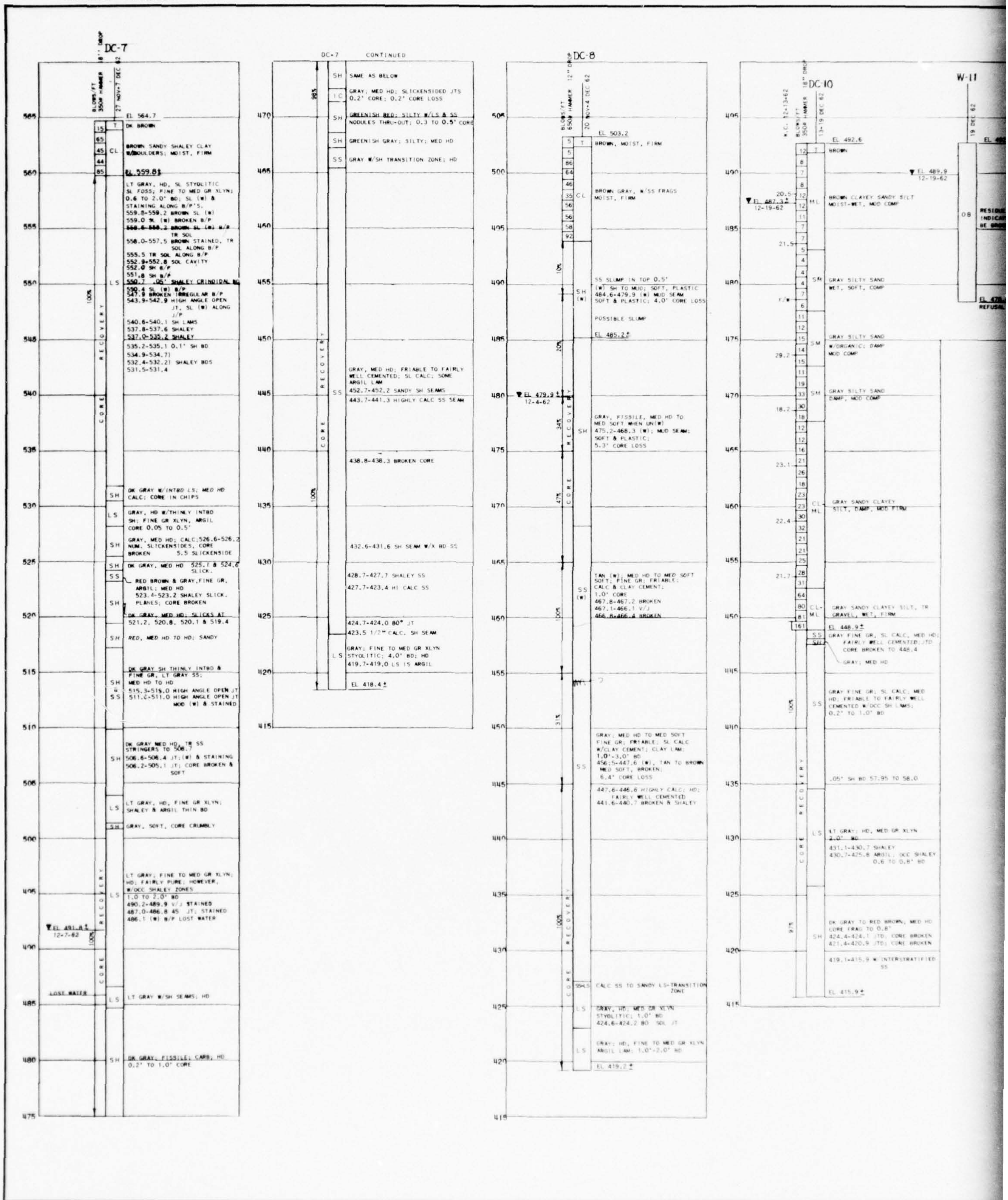
U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

DESIGNED:
DRAWN: C.L.B. TRACED:
CHECKED: HET
SUBMITTED:

WABASH RIVER BASIN
PATOKA RIVER RESERVOIR
PATOKA RIVER, ILLINOIS
BORING LOGS
SHEET 5

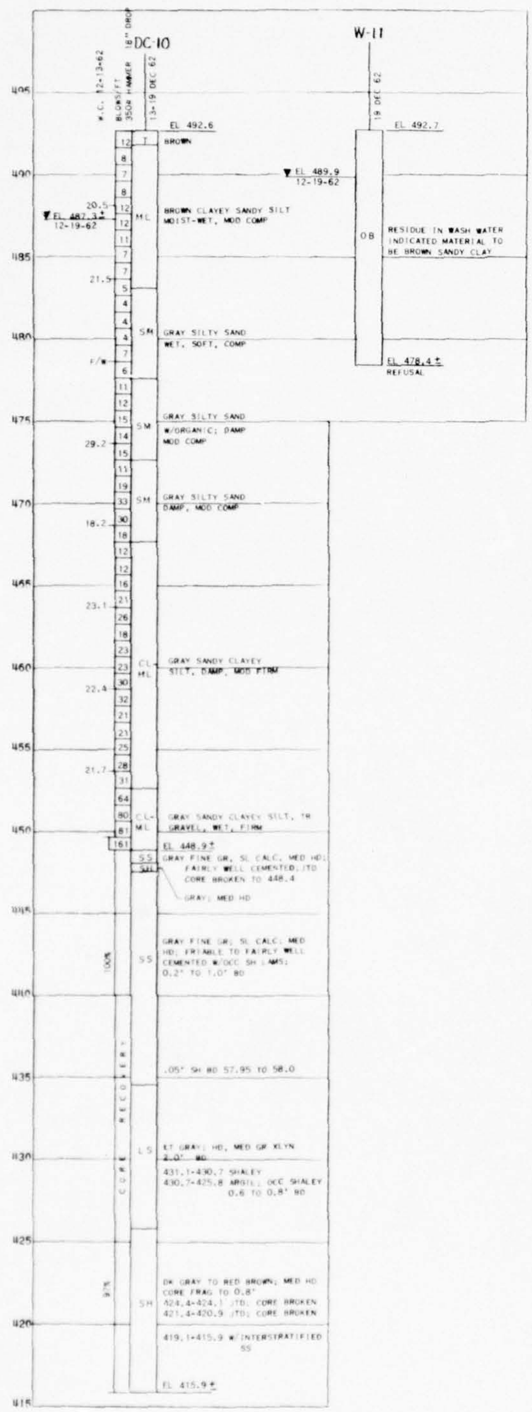
APPROVAL RECM: ASST. CHIEF ENGINEERING DIV.
APPROVED: COL., CORPS OF ENGINEERS DISTRICT ENGINEER DATE:
APPROVED: CHIEF, ENGINEERING DIVISION
SCALE:
DRAWING NUMBER

CORPS OF ENGINEERS



U.S. ARMY

2



REVISION	DATE	DESCRIPTION	BY

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

DESIGNED:
DRAWN: C.L.B. TRACED:
CHECKED: HEH
SUBMITTED:

WABASH RIVER BASIN
PATOKA RIVER RESERVOIR
PATOKA RIVER, ILLINOIS

BORING LOGS
SHEET 6

APPROVAL RECM: APPROVED: DATE:
ASST. CHIEF ENGINEERING DIV COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
APPROVED: SCALE:
DRAWING NUMBER
CHIEF, ENGINEERING DIVISION

CORPS OF ENGINEERS

UNIFIED SOIL CLASSIFICATION
(Including Identification and Description)

Major Divisions (1)	(2)		Group Symbols (3)	Typical Names (4)	Field Identification Procedures (Excluding particles larger than 3 inches and basing fractions on estimated weights) (5)	Information Required for Describing Soils (6)
Coarse-grained Soils. More than half of material is larger than NO. 200 sieve size. The NO. 200 sieve size is about the smallest particle visible to the naked eye.	Gravels. More than half of coarse fraction is larger than NO. 4 sieve size. (For visual classification, the 1/4-in. size may be used as equivalent to the NO. 4 sieve size)	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics.
			GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.	
		Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).	Give typical name, indicate approximate percentages of sand and gravel, max. size, angularity, surface condition, and hardness of the coarse grains, local or geologic name and other pertinent descriptive information, and symbol in parentheses.
			GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below).	
	Sands. More than half of coarse fraction is smaller than NO. 4 sieve size.	Clean Sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.	
			SP	Poorly-graded sands, gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.	
		Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).	Example: Silty sand, gravelly, about 20% hard, angular gravel particles 1/2-in. maximum size; rounded and subangular sand grains coarse to fine, about 15% nonplastic fines with low dry strength, well compacted and moist in place, alluvial sand; (SM).
			SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).	

Identification Procedures on Fraction Smaller than No. 40 Sieve Size

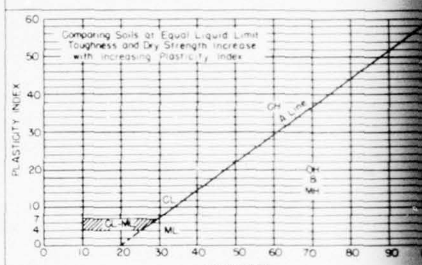
Major Divisions (1)	(2)	Group Symbols (3)	Typical Names (4)	Dry Strength (Crushing characteristics)	Dilatancy (Reaction to shaking)	Toughness (Consistency near PL)	Information Required for Describing Soils (6)
Fine-grained Soils. More than half of material is smaller than NO. 200 sieve size.	Silts and Clays. Liquid limit less than 50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight	Quick to slow	None	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	None to very slow	Medium	
		OL	Organic silts and organic silty clays of low plasticity.	Slight to medium	Slow	Slight	
	Silts and Clays. Liquid limit greater than 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium	Slow to none	Slight to medium	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions.
		CH	Inorganic clays of high plasticity, fat clays.	High to very high	None	High	
		OH	Organic clays of medium to high plasticity, organic silts.	Medium to high	None to very slow	Slight to medium	Example: Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML).
Highly Organic Soils		Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture.			

Laboratory Classification Criteria (7)

Use grain-size curve in identifying the fractions as given under field identification.

Determine percentages of gravel and sand from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse-grained soils are classified as follows:
- Less than 5% — GW, GP, SW, SP.
- More than 12% — GM, GC, SM, SC.
- 5% to 12% — Borderline cases requiring use of dual symbols.

GW	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	
GP	Not meeting all gradation requirements for GW	
GM	Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
GC	Atterberg limits above "A" line with PI greater than 7	
SW	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	
SP	Not meeting all gradation requirements for SW	
SM	Atterberg limits below "A" line or PI less than 4	Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols.
SC	Atterberg limits above "A" line with PI greater than 7	



PLASTICITY CHART

For laboratory classification of fine-grained soils

(1) Boundary classifications: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well-graded gravel-sand mixture with clay binder. (2) All sieve sizes on this chart are U. S. standard.

FIELD IDENTIFICATION PROCEDURES FOR FINE-GRAINED SOIL OR FRACTIONS

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (Reaction to shaking)

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics)

After removing particles larger than No. 40 sieve size, mold a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit)

After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is molded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

Adopted by Corps of Engineers and Bureau of Reclamation, January 1952

R-O11953B

THE ABOVE CHART CONSISTS OF COMPLETE DATA AS INCLUDED IN CORPS OF ENGINEERS' UNIFIED SOIL CLASSIFICATION SYSTEM.
SOIL CLASSIFICATION NOT APPLICABLE TO THIS PROJECT SHALL BE DISREGARDED

LEGEND

F	= FILL	W/	= WITH
T	= TOP SOIL	GR	= GRAIN
OB	= OVERBURDEN (SEE GENERAL NOTE 4)	OCC	= OCCASIONAL
Ss	= SANDSTONE	BD	= BEDDED OR BEDS
SH	= SHALE	INTBD	= INTERBEDDED
SLS	= SILTSTONE	LAM	= LAMINAE
LS	= LIMESTONE	XLYN	= CRYSTALLINE
GN	= GRANITE	ARGIL	= ARGILLACEOUS
CO	= COAL	DOL	= DOLOMITE
UC	= UNDERCLAY	CAL	= CALCEROUS
(W)	= WEATHERED	CARBO	= CARBONACEOUS
▼	= GROUND WATER, ELEV. & DATE (SEE GENERAL NOTE 2)	AREN	= ARENACEOUS
WC	= WATER CONTENT (EXPRESSED IN % DRY WEIGHT) & DATE	VAU	= VAUGHNITIC
*	= CLASSIFICATION VERIFIED BY LABORATORY TESTS (SEE GENERAL NOTE 5)	FOS	= FOSSILIFEROUS
DC-10 7-26-56	BORING NO. & DATE MADE	FRAG	= FRAGMENTS
LT	= LIGHT	DIAG	= DIAGONAL
DK	= DARK	ALT	= ALTERNATING
SL	= SLIGHTLY	VERT	= VERTICAL
MOD	= MODERATELY	HOR	= HORIZONTAL
MED	= MEDIUM	FRAC	= FRACTURE
COMP	= COMPACT	CON	= CONGLOMERATE
HD	= HARD	X-BD	= CROSSBEDDING
TR	= TRACE	S/P	= SHEAR PLANE
F/W	= FREE WATER	V/J	= VERTICAL JOINT
		JT	= JOINT
		SOL	= SOLUTION
		▨	= CAVITY OR UNCONSOLIDATED MATERIAL
		MICA	= MICACEOUS
		STY	= STYLOLITIC
		GEOD	= GEODIFEROUS
		QTZ	= QUARTZ
		PS	= PISTON SAMPLER
		CL	= CORE LOSS

LEGEND FEATURES NOT APPLICABLE TO THIS PROJECT SHALL BE DISREGARDED

GENERAL NOTES

1. REFUSAL IS DEFINED AS THE POINT BEYOND WHICH FURTHER PENETRATION WAS IMPOSSIBLE WITH THE EXPLORATION METHOD USED. SEE "METHODS OF EXPLORATION" THIS SHEET INDICATING MEANS BY WHICH THE BORINGS WERE ADVANCED.
2. WATER ELEVATIONS INDICATED (▼) IN CORE (C), FISHTAIL (F), DENISON (U) AND WASH (W) BORINGS MAY HAVE BEEN INFLUENCED BY TRAPPED DRILLING WATER AND SHOULD NOT BE CONSTRUED AS INDICATING THE TRUE GROUND WATER LEVEL.
3. GROUND WATER LEVELS WILL VARY IN ACCORDANCE WITH RAINFALL AND STREAM STAGES, THEREFORE, ACTUAL LEVEL OF GROUND WATER ON ANY DATE OTHER THAN THAT SHOWN ON THE LOGS MUST BE DETERMINED BY SEPARATE OBSERVATIONS. THE OMISSION OF GROUND WATER ELEVATIONS SHALL NOT NECESSARILY BE CONSTRUED AS INDICATING THE ABSENCE OF GROUND WATER AT A PARTICULAR BORING LOCATION.
4. WHEREVER THE METHOD OF EXPLORATION PRECLUDED THE POSSIBILITY OF RECOVERING SAMPLES ABOVE ROCK, SUITABLE FOR EXAMINATION OR TESTS, THE MATERIAL IS DENOTED AS OVERBURDEN, HOWEVER WHERE POSSIBLE THE OVERBURDEN RESIDUE IN THE DRILLING WATER WAS VISUALLY CLASSIFIED IN THE FIELD AND IS SO DENOTED ON THE BORING LOG.
5. CLASSIFICATIONS AND PHYSICAL CHARACTERISTICS OF SOIL AND ROCK AS SHOWN ON THE LOGS WERE DETERMINED IN THE FIELD AND LATER SUPPLEMENTED BY ANALYSIS MADE BY THE DISTRICT GEOLOGIST AND THE LABORATORY TECHNICIANS. CLASSIFICATIONS OF MATERIALS VERIFIED BY ATTERBERG LIMIT TESTS ARE DENOTED BY AN ASTERISK. ATTERBERG LIMITS WERE DETERMINED IN ACCORDANCE WITH ASTM D 423-54T AND ASTM D 424-54 T.
6. FIELD BOOKS, FIELD LOGS, LABORATORY LOGS (PRESENTING THE RESULTS OF LABORATORY TESTS FOR SHEAR, CONSOLIDATION, PERMEABILITY, ETC. WHEN PERFORMED) AND EDITED LOGS MAY BE VIEWED IN THE OFFICE OF THE DISTRICT ENGINEER, U.S. ARMY ENGINEER DISTRICT, LOUISVILLE, CORPS OF ENGINEERS, 830 WEST BROADWAY, LOUISVILLE, KENTUCKY. FAILURE OF THE CONTRACTOR TO AVAIL HIMSELF OF THE INFORMATION REPRESENTED BY THE BORING LOGS, INCLUDING LABORATORY TEST RESULTS, SHALL NOT BE GROUNDS FOR A CLAIM THAT THE GOVERNMENT WITHELD INFORMATION ON SUBSURFACE CONDITIONS.
7. THE TERM "LOST WATER" AS SHOWN ON THE LOGS INDICATES A QUANTITY OF DRILLING WATER LOST IN THE DRILL HOLE IN EXCESS OF 40 GALLONS PER MINUTE.

METHODS OF EXPL

- HA = HAND AUGE
- A = POWER AUG
- C = CORE BORIN
- D = DRIVE SAMP
- F = FISHTAIL
- U = UNDISTURBE
- W = WASH BORIN
- T = TRENCH
- TP = TEST PIT
- R = ROCK BIT
- P = PROBE ROD

NOTE: THE LETTER DESIGNATION USED BE METHOD OF EXPLORATION, FOR EXAM

DRIVE SAMPLES WERE TAKEN WITH A 2 SAMPLER USING A 350# HAMMER WITH INDICATED ON GRAPHIC LOGS

…ured for
…Soils

Laboratory Classification Criteria

7

…add information
…gree of compact-
…oisture conditions
…eristics.

…dicate approximate
… and gravel, max.
…urface condition,
… coarse grains,
…ame and other
…e information,
…theses.

… about 20% hard,
…icles 1/2-in.
…led and subangular
…o fine, about 15%
…th low dry strength,
…moist in place, al-

…dicate degree and
…y, amount and
…rse grains, color
…lor if any, local or
…other pertinent
…tion, and symbol

…s add information
…tification, con-
…urbed and re-
…isture and drain-

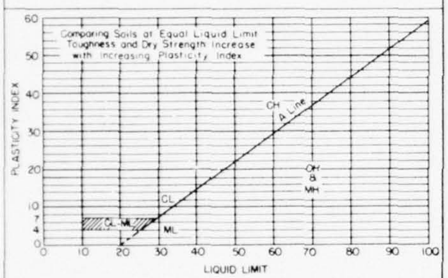
…, slightly plastic,
… of fine sand,
… root holes, firm
…, loess, (ML).

Use grain-size curve in identifying the fractions as given under field identification.

Determine percentages of gravel and sand from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse-grained soils are classified as follows:

Less than 5% — GW, GP, SW, SP,
More than 12% — GM, GC, SM, SC
5% to 12% — Borderline cases requiring use of dual symbols

$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	
Not meeting all gradation requirements for GW	
Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are *borderline* cases requiring use of dual symbols.
Atterberg limits above "A" line with PI greater than 7	
$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	
Not meeting all gradation requirements for SW	
Atterberg limits below "A" line or PI less than 4	Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols.
Atterberg limits above "A" line with PI greater than 7	



PLASTICITY CHART

For laboratory classification of fine-grained soils

… gravel-sand mixture with clay binder. (2) All sieve sizes on this chart are U.S. standard.

…OR FRACTIONS
…in. For field classification purposes,
… with the tests.

Toughness (Consistency near plastic limit)

After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is molded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is *the colloidal clay fraction in the soil. Weakness of the thread at the* plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

R-0119538

…S' UNIFIED SOIL CLASSIFICATION SYSTEM.

SPECIAL NOTES

1. CLASSIFICATION OF SOIL, SAND AND GRAVEL ENCOUNTERED IN BORINGS DRILLED PRIOR TO 1952 ARE IN ACCORDANCE WITH MASSACHUSETTS INSTITUTE OF TECHNOLOGY (M.I.T.) CLASSIFICATION SYSTEM. CLASSIFICATION OF MATERIAL ENCOUNTERED AFTER 1952 ARE IN ACCORDANCE WITH CORPS OF ENGINEERS UNIFIED SOIL CLASSIFICATION SYSTEM.

FOLLOWING NOTES RELATIVE TO BORINGS DRILLED PRIOR TO JANUARY 1952

1. IDENTIFICATION BASED ON FOLLOWING GRAIN SIZE RANGES
   GRAVEL — 3 INCH TO #10 SIEVE
   SAND — #10 TO #200 SIEVE
   FINES — (SILT OR CLAY) BE #200 SIEVE
2. SOIL IS CALLED SILT OR CLAY BASE UPON ATTERBURG LIMITS VALUES OF MINUS 40 MESH FRACTION AS FOLLOWS:
   SILT: L.L. 28 OR LESS & PI 6 OR LESS
   CLAY: LL OVER 28 OR PI OVER 6
3. SIEVE SIZES ARE US STANDARD
4. DESCRIPTION OF CLAY:
   LEAN CLAY: LL OVER 28, LESS THAN 35
   MED. CLAY: LL OVER 35, LESS THAN 50
   FAT CLAY: LL OVER 50 LESS THAN 60
   VERY FAT CLAY: LL OVER 60
5. IDENTIFICATION OF MINOR QUANTITES FROM 1949 TO 1952:
   TR. OF CLAY CONTAINS 3 TO 10% CLAY
   TR. OF GRAVEL CONTAINS 5 TO 15% GRAVEL
   TR. OF SAND CONTAINS 5 TO 20% SAND
6. IDENTIFICATION OF MINOR QUANTITIES PRIOR TO 1949:
   TR. (TRACE) 1 TO 10%
   LT. (LITTLE) 10 TO 20%
   SM. (SOME) 20 TO 30%
   & 30 TO 50%

…S

…ER PENETRATION WAS IMPOSSIBLE WITH THE
…ON" THIS SHEET INDICATING MEANS BY WHICH

…, DENISON (U) AND WASH (W) BORINGS
… AND SHOULD NOT BE CONSTRUED AS INDICATING

…NFALL AND STREAM STAGES, THEREFORE ACTUAL
…HOWN ON THE LOGS MUST BE DETERMINED BY
…ELEVATIONS SHALL NOT NECESSARILY BE
… AT A PARTICULAR BORING LOCATION.

…POSSIBILITY OF RECOVERING SAMPLES ABOVE ROCK,
…NOTED AS OVERBURDEN, HOWEVER WHERE
…ER WAS VISUALLY CLASSIFIED IN THE FIELD

… AND ROCK AS SHOWN ON THE LOGS WERE
…Y ANALYSIS MADE BY THE DISTRICT GEOLOGIST
…MATERIALS VERIFIED BY ATTERBERG LIMIT TESTS
…ERE DETERMINED IN ACCORDANCE WITH

…NTING THE RESULTS OF LABORATORY TESTS
…N PERFORMED) AND EDITED LOGS MAY BE
…S. ARMY ENGINEER DISTRICT, LOUISVILLE,
…VILLE, KENTUCKY. FAILURE OF THE
…TION REPRESENTED BY THE BORING LOGS,
…OT BE GROUNDS FOR A CLAIM THAT THE
…ACE CONDITIONS

… INDICATES A QUANTITY OF DRILLING WATER LOST
…ER MINUTE

METHODS OF EXPLORATION

HA = HAND AUGER
A = POWER AUGER
C = CORE BORING
D = DRIVE SAMPLER
F = FISHTAIL
U = UNDISTURBED DENISON
W = WASH BORING
T = TRENCH
TP = TEST PIT
R = ROCK BIT
P = PROBE ROD

NOTE: THE LETTER DESIGNATION USED BEFORE BORING NUMBER INDICATES THE METHOD OF EXPLORATION, FOR EXAMPLE: DC = DRIVE SAMPLER AND CORE BORING.

DRIVE SAMPLES WERE TAKEN WITH A $2\frac{1}{2}''$ I.D.-3" O.D. X 5' SOLID BARREL SAMPLER USING A 350# HAMMER WITH AN 18" DROP, UNLESS OTHERWISE INDICATED ON GRAPHIC LOGS

REVISION	DATE	DESCRIPTION	BY

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
LOUISVILLE, KENTUCKY

DESIGNED BY:
DRAWN BY: C.T.B.
TRACED BY:
CHECKED BY: JET
SUBMITTED:
ASST. CHIEF, ENGINEERING DIV.
APPROVED:
CHIEF, ENGINEERING DIVISION
APPROVED:
DATE:

SOIL CLASSIFICATION CHART AND LEGENDS

APPROVED: DATE:
COL. CORPS OF ENGINEERS, DISTRICT ENGINEER

SCALE:

DRAWING NUMBER

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

INTERIM REPORT NO. 2
WABASH RIVER BASIN
COMPREHENSIVE STUDY
COVERING RESERVOIR SITES
ON
EMBARRASS RIVER, ILLINOIS
AND
CLIFTY CREEK AND PATOKA RIVER, INDIANA

APPENDIX F

REPORTS OF OTHER AGENCIES

JANUARY 1964

INTERIM REPORT NO. 2
WABASH RIVER BASIN
COMPREHENSIVE STUDY
COVERING RESERVOIR SITES
ON
EMBARRASS RIVER, ILLINOIS
AND
CLIFTY CREEK AND PATOKA RIVER, INDIANA

APPENDIX F - REPORTS OF OTHER AGENCIES

Exhibit F-1	U. S. Department of Agriculture, Soil Conservation Service (Letter reports dated 13, 27 and 8 November 1963 on Lincoln, Clifty Creek and Patoka Reservoirs, respectively, supplemental letters dated 17 December 1963, Patoka River Subbasin Map and Table showing Potential Impoundment Sites)
Exhibit F-2	U. S. Department of the Interior Geological Survey (Ground-water appraisal report dated February 1964, geological maps (Fugures 1 through 4) and Summary of ground-water hydrogeologic relationships (Table 1) of the Embarrass River basin; letter report dated 3 December 1963 on Clifty Creek Reservoir; and Ground-water appraisal report dated November 1963, geological maps (Fugures 1 through 4) and Summary of ground-water hydrogeologic relationships (Table 1) of the Patoka River basin)
Exhibit F-3	U. S. Department of the Interior, Fish and Wildlife Service, (Letter report dated 22 January 1963 on Lincoln Reservoir, and District Engineer's comments, dated 28 February 1964; Letter report dated 16 January 1964 on Clifty Creek Reservoir, and District Engineer's comments, dated 28 February 1964; and Letter Report dated 22 January 1964 on Patoka Reservoir, and District Engineer's comments, dated 5 March 1964)
Exhibit F-4	U. S. Department of the Interior, Bureau of Outdoor Recreation (Reconnaissance Report on the Recreation Resources of Lincoln Reservoir with comments of the State of Illinois, dated 3 March 1964, relative to the report, Reconnaissance Reports on the Recreation Resources of Clifty Creek and Patoka Reservoirs, with comments of the State of Indiana, dated 3 March 1964, relative to the reports, and comments of the Forest Service, dated 3 March 1964, relative to the Report on Patoka Reservoir)
Exhibit F-5	U. S. Department of the Interior, Bureau of Mines (Report dated November 1963 on Lincoln and Clifty Creek Reservoirs and 10 October 1963 on Patoka Reservoir)

Rev 16 Mar 1964

Exhibit F-6	U. S. Department of Health, Education and Welfare, Public Health Service (General Appraisal Study of Lincoln, Clifty Creek and Patoka Reservoirs, dated January 1964)
Exhibit F-7	Federal Power Commission (Letter reports dated 21, 2 October, 1963 on Lincoln and Patoka Reservoirs and 13 November 1963 on Clifty Creek Reservoir)
Exhibit F-8	U. S. Department of Agriculture, Forest Service (Letter dated 29 October 1963 on Patoka Reservoir, with District Engineer's replys, dated 14 November 1963; and letter dated 13 December 1963 on Patoka Reservoir)
Exhibit F-9	City of Charleston, Illinois (Letter dated 4 March 1964 relative to Lincoln Reservoir)
Exhibit F-10	Indiana Flood Control and Water Resources Commission (Letter dated 24 December 1963 on Patoka Reservoir)

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Room 506, 611 North Park Avenue
Indianapolis 4, Indiana 46204

November 13, 1963

Colonel Willard Roper, District Engineer
U. S. Army Engineer District, Louisville
Corps of Engineers
P. O. Box 59
Louisville 1, Kentucky

Dear Colonel Roper:

In regard to your letter of August 22, 1963 concerning special studies by the Department of Agriculture in connection with selected Corps of Engineers' structures, the following letter report is submitted concerning the Embarrass River Basin area adjacent to, and above the proposed Lincoln Reservoir. Within the time and funds available, it was impossible to make a detailed investigation of the small watershed potential or the future requirements of irrigation in detail; however, in order to cooperate as much as possible under the circumstances, we have made a reconnaissance-type study of the area immediately adjacent to and above the proposed Lincoln Reservoir site in order to determine project potentials and the area of the main stream below the Lincoln Reservoir for irrigation potential.

The reconnaissance-type survey and evaluation included eleven small watersheds to determine the extent of project feasibility. It was found that water storage opportunities in the tributary area are very limited. The principal structural program to alleviate flood problems and to provide proper drainage outlets would involve channel improvements. Those floodwater retarding and multiple-purpose sites and the length of channel improvements considered are shown in the attached table.

Since the majority of these projects require improved channel conditions to provide flood protection and drainage outlets, we have included in the attached table the estimated elevation at which flooding of tributaries begins at their confluence with the main channel of the Embarrass River and the estimated distance upstream that the elevation of 610 and 634 would affect each tributary. In order to provide proper outlet for the extensive areas that need drainage outlet improvement in each of the designated tributary streams, it would appear imperative that consideration of outlet elevations and backwater effects from the proposed Corps' structure should be given in the design, and the regulation and operation schedule of the seasonal and flood pools of the Lincoln Reservoir

If this is done, those projects which are indicated to have questionable feasibility with the Lincoln Reservoir in place may become feasible projects.

Consideration was given to sixteen potential impoundment sites. Of these, only nine would provide sufficient floodwater retarding storage. These nine also showed a combined potential of 22,912 acre feet of storage available for other uses. No assessment has been made of the total benefits that might be credited to multiple use of these sites. Four of these sites would be directly affected by the proposed Lincoln Reservoir.

Our investigation of irrigation potentials in the Embarrass River Basin adjacent to the main stream, below the proposed Lincoln Reservoir, indicates that within the foreseeable future no extensive irrigation development in this basin is anticipated.

It is our understanding that during project formulation studies for the Wabash River Basin Comprehensive Report the potential upstream watershed projects and the plans for the Lincoln Reservoir will be closely coordinated.

Sincerely yours,

/s/ C. E. Swain

Enclosures

C. E. Swain
State Conservationist

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Room 506, 611 North Park Avenue
Indianapolis 4, Indiana, 46204

November 27, 1963

Colonel Willard Roper, District Engineer
U. S. Army Engineer District, Louisville
Corps of Engineers
P. O. Box 59
Louisville 1, Kentucky

Dear Colonel Roper:

In regard to your letter of August 22, 1963 concerning special studies by the Department of Agriculture in connection with selected Corps of Engineers' structures, the following letter report is submitted concerning the Clifty Creek watershed area adjacent to the proposed Hartsville Reservoir site. Within the time and funds available, it was impossible to make a detailed investigation of the small watershed potential or the future requirements for irrigation; however, in order to co-operate as much as possible under these circumstances, we have made a reconnaissance-type study of the area relative to this information.

Due to topographic conditions, generally limited flood plain areas throughout the watershed, and the types of works [illegible] of improvement that can be considered, an upstream watershed project would not be feasible in the main stream area of Clifty Creek. Further consideration will be given at a later date, in the course of our normal studies, to upstream watershed project potentials in the Clifty Creek Watershed, generally above Milford, Indiana, Fall Creek above the Bartholomew-Decatur County Line, and on Duck Creek. It is not anticipated that the proposed Hartsville Reservoir will have any affect on these projects. Subsequent upstream project studies will be coordinated with plans for the proposed Hartsville structure.

Through the efforts of the Soil Conservation Districts and the assistance of the agencies concerned in land and water resources, the farmers of the Clifty Creek watershed area should be encouraged to continue, and to accelerate, insofar as possible, the installation of conservation land treatment measures on the upland areas. This will improve hydrologic conditions of the watershed and stabilize potential sediment source areas through the reduction of sheet and gully erosion and proper land utilization.

Our studies of irrigation potentials, adjacent to, and below the proposed Hartsville structure indicate that presently there are 1,110 acres of field and truck crops being irrigated in the area along Clifty Creek, and the East Fork of the White River down to the Bartholomew-Jackson County Line. Of this 1,110 acres, 220 acres lie along Clifty Creek, with the remaining 890 acres lying along the East Fork of the White River. Crops presently irrigated include vegetables, sweet corn, field corn, tomatoes and tobacco. Presently, there is one food processing plant located at Columbus, Indiana, one at Austin, Indiana, and one at Franklin, Indiana. Future expansion of these plants could result in an expansion of irrigated acreages. It is estimated that there are 17,000 acres of land in the Clifty Creek and the East Fork of the White River bottoms to the county line that could be irrigated if the water were available and production requirements necessitated this use. If the present rate of increase in the use of irrigation continues for the next fifteen years, it is anticipated that approximately 4,000 acres would be under supplemental-type irrigation by 1978.

Further evaluations of future irrigation requirements of the Wabash Basin in more detail will be made during the normal course of the planned USDA studies for the comprehensive report.

If we can be of further assistance, please advise.

Sincerely yours,

/s/ Frank R. Brower, Jr.

for C. E. Swain
State Conservationist

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
Room 506, 611 North Park Avenue
Indianapolis 4, Indiana, 46204

November 8, 1963

Colonel Willard Roper, District Engineer
U. S. Army Engineer District, Louisville
Corps of Engineers
P. O. Box 59
Louisville 1, Kentucky

Dear Colonel Roper:

In regard to your letter of request of August 22, 1963 concerning special studies by the Department of Agriculture in connection with selected Corps of Engineer structures, the following letter report is submitted concerning the Upper Patoka River Basin and the Patoka structure watershed. Within the time and funds available, it has been impossible to obtain the information requested in any degree of detail; however, in order to cooperate as much as possible under these circumstances, we have made a reconnaissance-type study of the area immediately adjacent to the Patoka site and have evaluated structural works and flood problems with limited detail to show project potentials. You recognize that much of the information requested now would have been developed during the course of our regularly scheduled studies and would have been available in the project formulation stage.

This reconnaissance-type review included the drainage area of the Patoka River Basin above Jasper, Indiana, consideration of twenty potential upstream impoundment structures, approximately 57 miles of channel improvements, and consideration of the general magnitude of the benefits to flood prevention in the floodplain areas above Jasper, Indiana. Based on our studies, we find that we cannot economically justify a small watershed protection project in this area on the basis of flood prevention under present criteria. The estimated average annual flood prevention benefits to approximately 12,800 acres of floodplain area is $95,000 with an average annual cost for the structural works of improvement of $176,450, or a B:C ratio of 0.54:1.

No assessment has been made of the total benefits to multiple use of these twenty sites for the storage of additional water for recreation, low flow augmentation, or other uses. Had there been sufficient time, these benefits could have been obtained by joint consideration of the data secured by your agency from the Bureau of Outdoor Recreation and the Public

Health Service, and the coordination of these benefits to the additional storage potentials of the sites shown on the attached table. In this regard it can be seen from the tabular data that use of six sites (I, VI, VIII, IX, XIV, XVI) would provide a total surface area of approximately 4,100 acres for recreation with a volume of additional storage of 110,000 acre feet for use in recreation. The remaining fourteen structures would provide a surface area of 3,000 acres with 82,000 acre feet which could be considered for low flow augmentation.

It would be desirable to establish closer coordination between our two river basin staffs in appraisal of flood prevention, recreation, low flow augmentation, and other benefits particularly where the effects of the Corps' projects and upstream watershed projects are to be considered and where consideration is to be given to possible alternative solutions. This will be particularly important during the program formulation and evaluation period for the final comprehensive report on the Wabash River Basin.

We shall, in the further course of our studies, give consideration to additional upstream watershed project potentials in the area below Jasper, Indiana and consider their combined effects during project formulation.

Our investigation of irrigation potentials in the Patoka River Basin adjacent to the main stream, below the proposed Patoka structure, indicates that within the foreseeable future no extensive irrigation development in this basin is anticipated.

As stated in our earlier telephone conversation with your office, a report will be furnished you on the Lincoln Reservoir site in the near future.

We believe it would be desirable to discuss the material of these projects with you in person at the first opportunity. In the meantime, if we can be of further assistance to you, please advise.

Sincerely yours,

/s/ C. E. Swain

C. E. Swain
State Conservationist

Enclosures

Exhibit F-1

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Room 506, 611 North Park Avenue
Indianapolis 4, Indiana, 46204

December 17, 1963

Colonel Willard Roper, District Engineer
U. S. Army Engineer District, Louisville
Corps of Engineers
P. O. Box 59
Louisville 1, Kentucky

Dear Colonel Roper:

In regard to our letter report dated November 13, 1963 to you covering our watershed studies of the upper Embarrass River and the area adjacent to the proposed Lincoln Reservoir, the following comments are submitted as a supplement to that report.

Our original report, and comments related thereto, was based on elevation data furnished by your office indicating that the proposed seasonal pool elevation was to be 610 feet. Based upon this elevation our reconnaissance-type evaluation of the eleven potential upstream watershed projects indicated that five of these might be affected by the proposed reservoir, depending upon the reservoir regulation schedule and backwater affects of various flood elevations above the seasonal pool.

Subsequent to our report, a conference was held with representatives of your office concerning the regulation schedule and backwater affects for various pool elevations. At this time it was pointed out by your representatives that the land easements or flowage rights would be taken 5 feet vertically above the 80-year frequency pool, or to Elevation 634. At this frequency your preliminary study indicated that there would be no flooding above this elevation of 634.

As a result of this conference it is our opinion that the Lincoln Reservoir, as proposed in the public hearing at Charleston, Illinois December 10, 1963, would not have an adverse affect on the drainage of lands lying above Elevation 634. It is our understanding that the adequacy of outlet channel conditions below 634 feet would be considered and provided for in the final design of the proposed reservoir.

Sincerely yours,

/s/ W. T. Moon

for C. E. Swain
State Conservationist

Exhibit F-1

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
Room 506, 611 North Park Avenue
Indianapolis 4, Indiana, 46204

December 17, 1963

Colonel Willard Roper, District Engineer
U. S. Army Engineer District, Louisville
Corps of Engineers
P. O. Box 59
Louisville 1, Kentucky

Dear Colonel Roper:

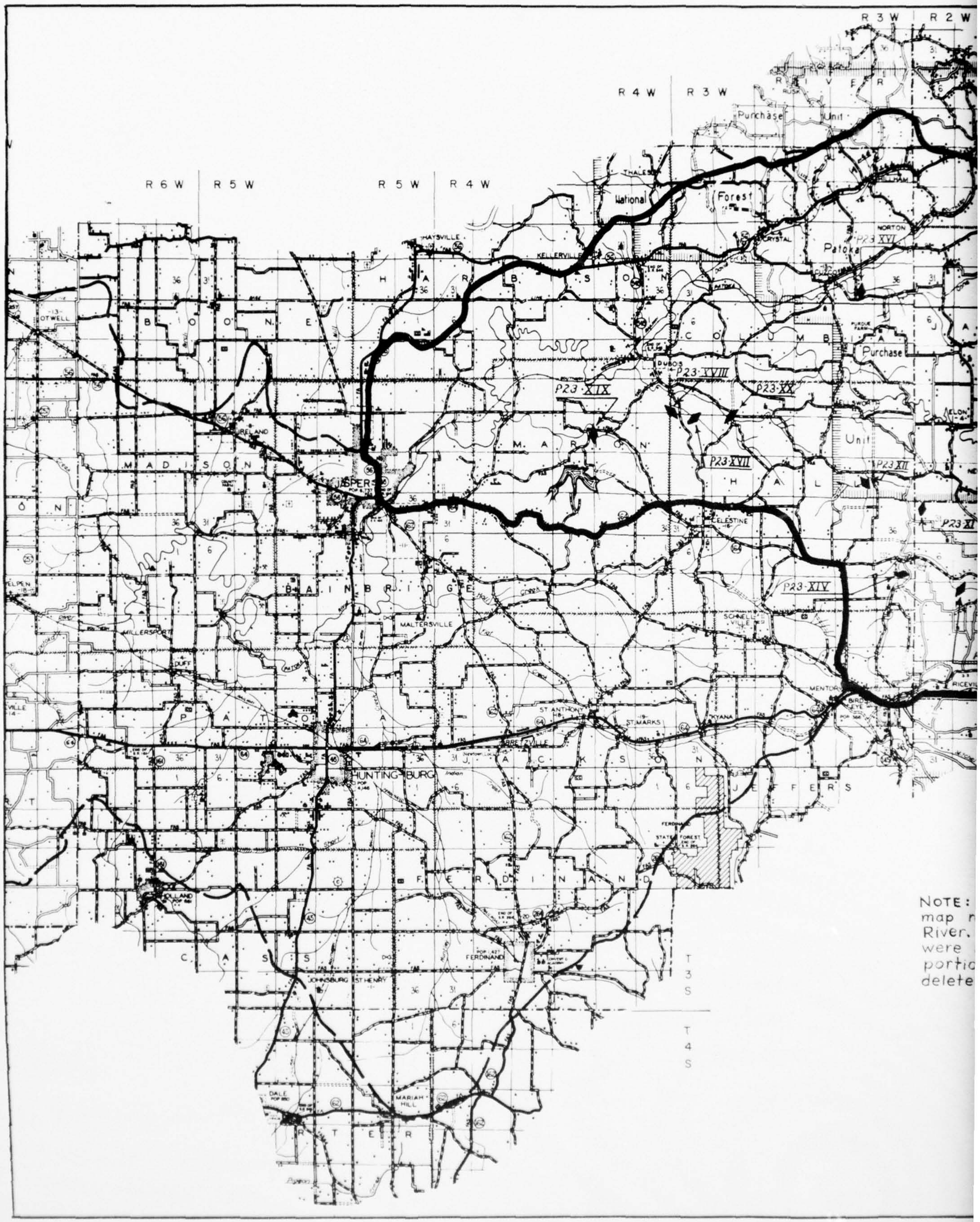
Reference is made to our letter report dated November 8, 1963 concerning the upstream watershed potential in the Patoka River Basin above Jasper, Indiana.

As indicated in that report, no assessments were made of the project for benefits from possible multiple use of water storage potentials in the twenty flood water retarding sites considered. The elevations, volumes and surface acres shown in the tabulated data for the twenty sites shown as "Potential Multiple Purpose Use" are based entirely on the estimated physical limitations of the sites themselves as determined from the USGS Quadrangle maps. Time and available data did not permit the development of water budgets or watershed yield data for the determination of storage input or recharge potentials for these sites.

Sincerely yours,

/s/ W. T. Moon

for C. E. Swain
State Conservationist



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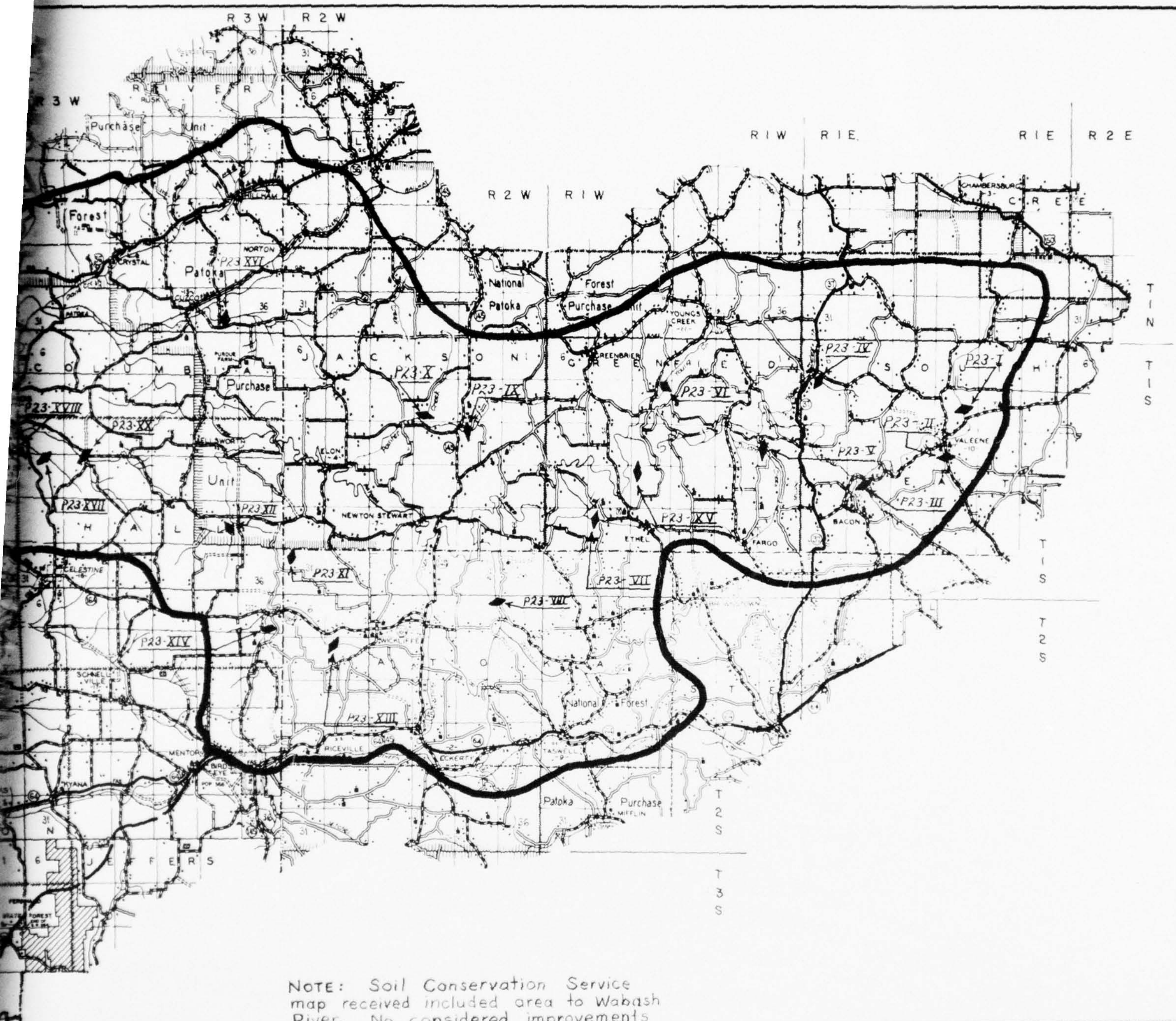

NOTE: Soil Conservation Service map received included area to Wabash River. No considered improvements were shown below Jasper and that portion of the map has been deleted in this presentation.

T 3 S

T 4 S

THE WABASH RIVER BASIN
PATOKA RIVER SUBBASIN

CRAWFORD, DUBOIS, GIBSON, MARTIN, ORANGE, PIKE, SPENCER, AND WARRICK COUNTIES, INDIANA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Date	Approved by
Designed	Title
Drawn	Title
Traced	Sheet No. 1 of 1 — Drawing No. 3-E-46659
Checked	

2

Exhibit F-1

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Patoka River Basin

Hydrologic Unit 23

Potential Impoundment Sites for Floodwater

Retarding and Multiple Purpose Uses

Site No.	Drainage Area	Flood Prevention Storage AC FT	Cost Single Purpose FP only $	Potential Multiple Purpose Use: Elev. Perm. Pool	Volume Perm. Pool AC FT	Area Perm. Pool AC
I	12.4	4,629	182,000	665.0	20,169	880
II	2.6	832	129,000	674.0	4,284	130
III	4.4	1,666	88,000	645.0	9,104	310
IV	3.1	992	120,000	665.0	5,902	150
V	5.8	1,856	98,000	635.0	11,908	355
VI	8.5	3,173	159,000	613.0	15,639	510
VII	5.6	1,792	137,000	574.0	8,690	295
VIII	18.1	6,757	255,000	563.5	23,940	960
IX	6.6	2,288	130,000	595.0	12,250	430
X	2.3	736	72,000	585.0	4,580	130
XI	2.4	1,037	79,000	575.0	5,040	190
XII	4.0	1,280	84,000	555.0	6,660	250
XIII	3.1	992	74,000	645.0	5,980	188
XIV	8.8	3,285	138,000	595.0	17,740	600
XV	2.0	661	69,000	605.0	4,160	123
XVI	10.4	4,104	149,000	555.0	21,190	760
XVII	2.3	1,244	71,000	535.0	5,236	230
XVIII	2.4	1,024	70,000	545.0	5,060	190
XIX	2.2	704	85,000	559.5	3,100	340
XX	5.3	1,696	110,000	521.5	2,430	175
TOTAL	112.3	40,748	2,299,000		193,062	7,196

Exhibit F-1

WABASH BASIN COMPREHENSIVE STUDY

GROUND-WATER APPRAISAL OF THE EMBARRASS RIVER BASIN

AND

LINCOLN RESERVOIR SITE, ILLINOIS

by

Frank A. Watkins, Jr.

Prepared by the U. S. Geological Survey

in cooperation with

U. S. Corps of Engineers, Louisville District

February 1964

EXHIBIT F-2

WABASH BASIN COMPREHENSIVE STUDY

GROUND-WATER APPRAISAL OF THE EMBARRASS RIVER BASIN AND LINCOLN RESERVOIR SITE, ILLINOIS

by

Frank A. Watkins, Jr.

INTRODUCTION

This report appraises the ground-water resources, the ground-surface water relationships, and the chemical quality of the ground water in the Embarrass River Basin, with emphasis on the availability, adequacy, and useability of the ground water at the Lincoln Reservoir site as part of the study of the Wabash River Basin.

Information in this report is based on reports of the Illinois State Geological Survey, the Illinois State Water Survey, and on observations made during the current study of the Wabash River Basin.

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WABASH RIVER BASIN COMPREHENSIVE STUDY COVERING RESERVOIR SITES--ETC(U)

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CONCLUSIONS

Loss of water from the proposed reservoir is possible where the reservoir is underlain by buried bedrock valleys that are filled with unconsolidated deposits of Pleistocene age.

The sand and gravel in these unconsolidated deposits and the dolomite and limestone of Devonian age are sources of large supplies of ground water, although not necessarily at places where the water is needed.

HYDROLOGIC CONDITIONS IN THE EMBARRASS RIVER BASIN

1. The dry-weather yield of the basin is small, especially above the proposed dam site. The stream is dry frequently at the Camargo gage.
2. There is dry-weather pickup in the Embarrass River from the junction of Kickapoo Creek to the mouth of the river, except for a short reach about 1.5 miles above the proposed dam site.
3. Dry-weather pickup increases downstream from the Wisconsin glacial boundary.
4. Sandstone, shale, coal, and limestone of Pennsylvanian age are the sources of only small supplies of ground water due to the small permeability and lack of secondary openings in these rocks.
5. Shale of Mississippian age is not water yielding.

6. Dolomite and limestone of Devonian age are generally a source of small to moderate supplies of ground water. But in areas where the rocks are creviced larger supplies of ground water are possible.

7. Sand and gravel of Recent and Pleistocene ages in the buried bedrock valley, which coincides in general with the present valley in the lower part of the basin, are sources of large supplies of ground water.

8. Till, sand, and gravel of Pleistocene age, laid down in the buried bedrock valleys in the upper and central parts of the basin, are sources of moderate to large supplies of ground water where the sand and gravel is thick and areally extensive.

9. Sand and gravel interbedded with till of Pleistocene age is a source of small to moderate supplies but the sand and gravel is usually thin and not areally extensive.

10. Till of Pleistocene age is a source of small supplies of water from large diameter dug wells and is used only when there is no other source.

11. Chemical quality of the ground water from the bedrock is good, with total dissolved solids rangir from less than 300 to more than 500 ppm (parts per million). The chemical quality generally becomes poorer with increasing depth. The water is treated for municipal and industrial uses.

12. Chemical quality of the ground water from sand and gravel is generally good, with total dissolved solids ranging from about 200 to more than 800 ppm. The higher values occur in areas where the possibility of contamination is greatest. The water is usually of more uniform quality than that from bedrock sources. The water is treated for municipal and industrial uses.

13. During dry-weather periods deoxygenation is a problem for a short distance downstream from the mouth of Kickapoo Creek. This is due to the fact that the effluent from Charleston's sewage disposal plant is discharged into Kickapoo Creek. Impoundment of water will improve this quality condition.

14. Deoxygenation is not a problem from the Diona gage site downstream.

HYDROLOGIC CONDITIONS AT PROPOSED LINCOLN RESERVOIR SITE

1. Precipitation and runoff at the Lincoln Reservoir site are about average for the state. Precipitation averages about 36 inches annually and runoff averages about 10 inches annually based on long-term records.

2. There are some areas of apparent loss of water from the stream to ground water or by evapotranspiration above the dam site.

3. Areas of loss coincide, in general, with areas underlain by buried bedrock valleys filled with unconsolidated deposits, indicating that the losses may be to these deposits.

4. The largest of these areas of loss is north of the divide on the preglacial bedrock surface in the upper part of basin and includes more than half the water shed area above the dam site. Water in the reservoir at maximum pool stage will extend upstream and be impounded directly above several branches of a buried valley through which losses apparently occur during dry-weather periods. Ground-water levels indicate that the gradient is down the buried valley rather than toward the stream and that the water moves out of the basin to the west. The relatively low runoff figure for this area may be further evidence for this movement of water out of the basin.

5. The small loss of water upstream from the Riverview dam is probably due to the withdrawal of the water by the City of Charleston. Most of this water is probably returned to the stream by way of Kickapoo Creek. Some of the loss may be due to recharge to a buried channel and/or evapotranspiration.

6. An area of loss about 1.5 miles above the dam site coincides with the intersection of a buried valley with the channel of the Embarrass River. On October 18, 1963 the loss in this reach of the river was found to be about 0.5 cfs out of a total flow of 3.9 cfs, or about 13 percent of the flow. Water impounded at this point will increase the head by 85 to 90 feet and losses could be large. Water lost to this buried valley would probably be returned to the stream below Ste. Marie.

7. Losses in the pool area could be large due to the apparent large permeability and/or partially unsaturated condition of the sand and gravel aquifers in the buried bedrock valleys.
8. Sand and gravel is a source of large quantities of water especially in the buried bedrock channels. Moderate to large supplies are also available from sand and gravel interbedded with till and from dolomite and limestone bedrock in a small area in the northwest part of the basin.

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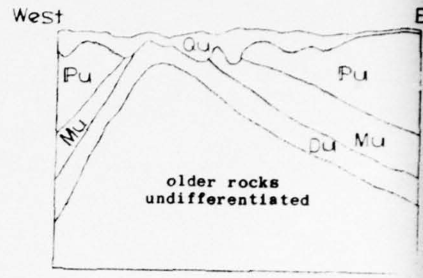
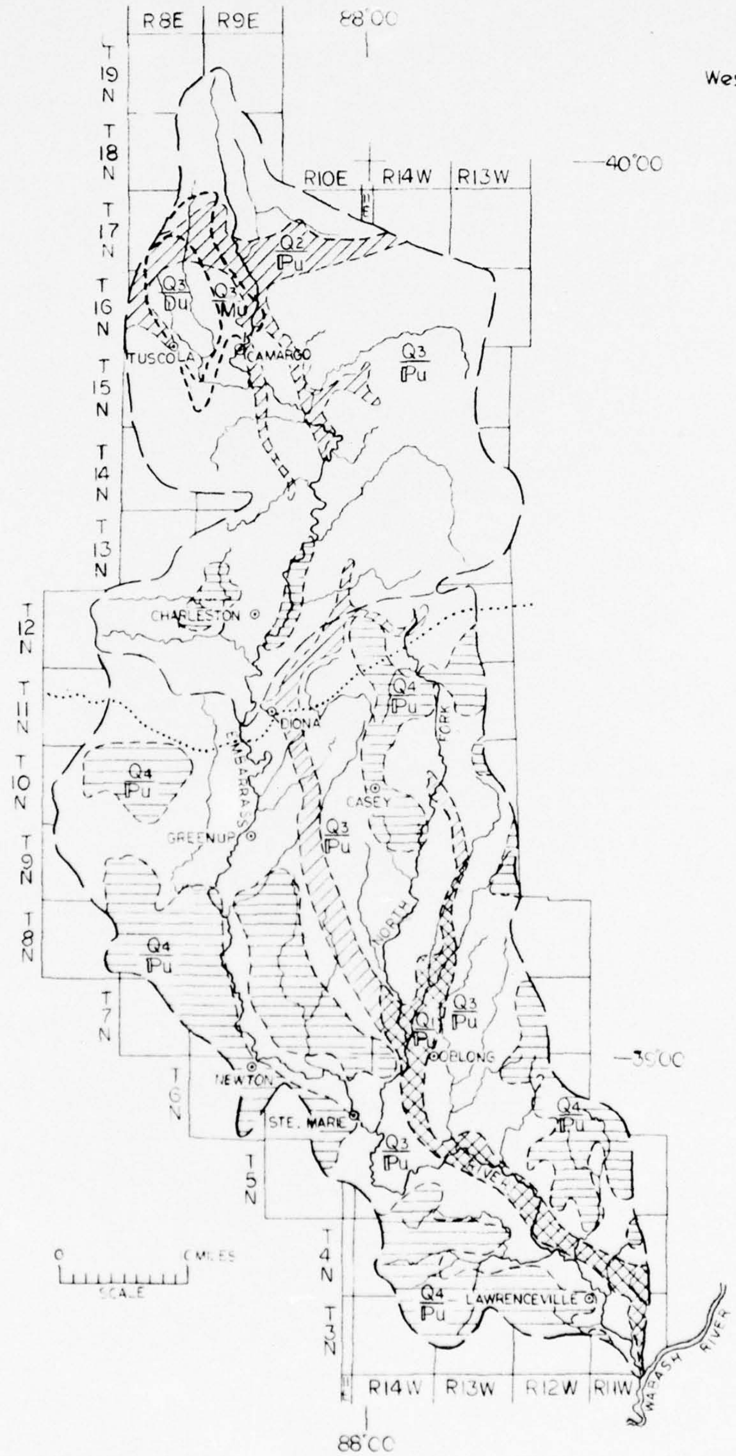


Generalized Geologic section across upper part of basin (not to scale)



Geology after the Illinois State Geological Survey

Quaternary System

Q1

Recent and Pleistocene Series

Sand and gravel, source of large supplies

Q2

Pleistocene Series

Till, sand and gravel, source of moderate to large supplies from sand and gravel

Q3

Pleistocene Series

Till, sand and gravel, includes some Recent alluvium, source of small to moderate supplies from sand and gravel

Q4

Pleistocene Series

Till, source of small supplies

FIGURE 1.--Geology controls availability of grou

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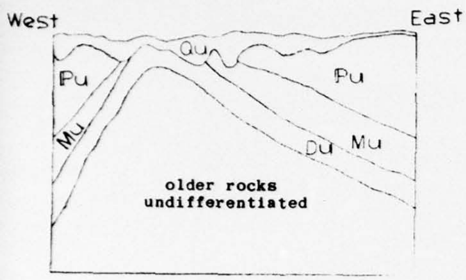

Generalized Geologic section across upper part of basin (not to scale)

Relative yields and water levels

	Yield (gpm)	Water Levels (feet below land surface)
Recent[a/]	<100	< 20
Q1 Recent and Pleistocene	300 to >2000	<30
Q2 Pleistocene	100 to >200	<70
Q3 Pleistocene (includes some Recent)	<20 to 100	0 to >100
Q4 Pleistocene	<10	<30
Pu Pennsylvanian	<20	<20 to >100
Mu Mississippian	Not water yielding	------------
Du Devonian	<20[b/]	>100

a/ Not shown on map or section

b/ Scattered wells reported to yield as much as 500 gpm

EXPLANATION

Quaternary System

Q1
Recent and Pleistocene Series

Sand and gravel, source of large supplies

Q2
Pleistocene Series

Till, sand and gravel, source of moderate to large supplies from sand and gravel

Q3
Pleistocene Series

Till, sand and gravel, includes some Recent alluvium, source of small to moderate supplies from sand and gravel

Q4
Pleistocene Series

Till, source of small supplies

Pennsylvanian System

Pu
undifferentiated

Sandstone, shale, coal and limestone; source of small supplies chiefly from sandstone

Mississippian System

Mu
undifferentiated

Shale, not water yielding

Devonian System

Du
undifferentiated

Dolomite and limestone, source of small to moderate supplies chiefly from dolomite and limestone; large supplies possible where creviced

Boundaries between water-bearing units in unconsolidated deposits

Subcrop of bedrock units

Wisconsin glacial boundary

Drainage divide

Q1
Pu

Upper symbol indicates surface deposit
Lower symbol indicates underlying bedrock

RE 1.--Geology controls availability of ground water

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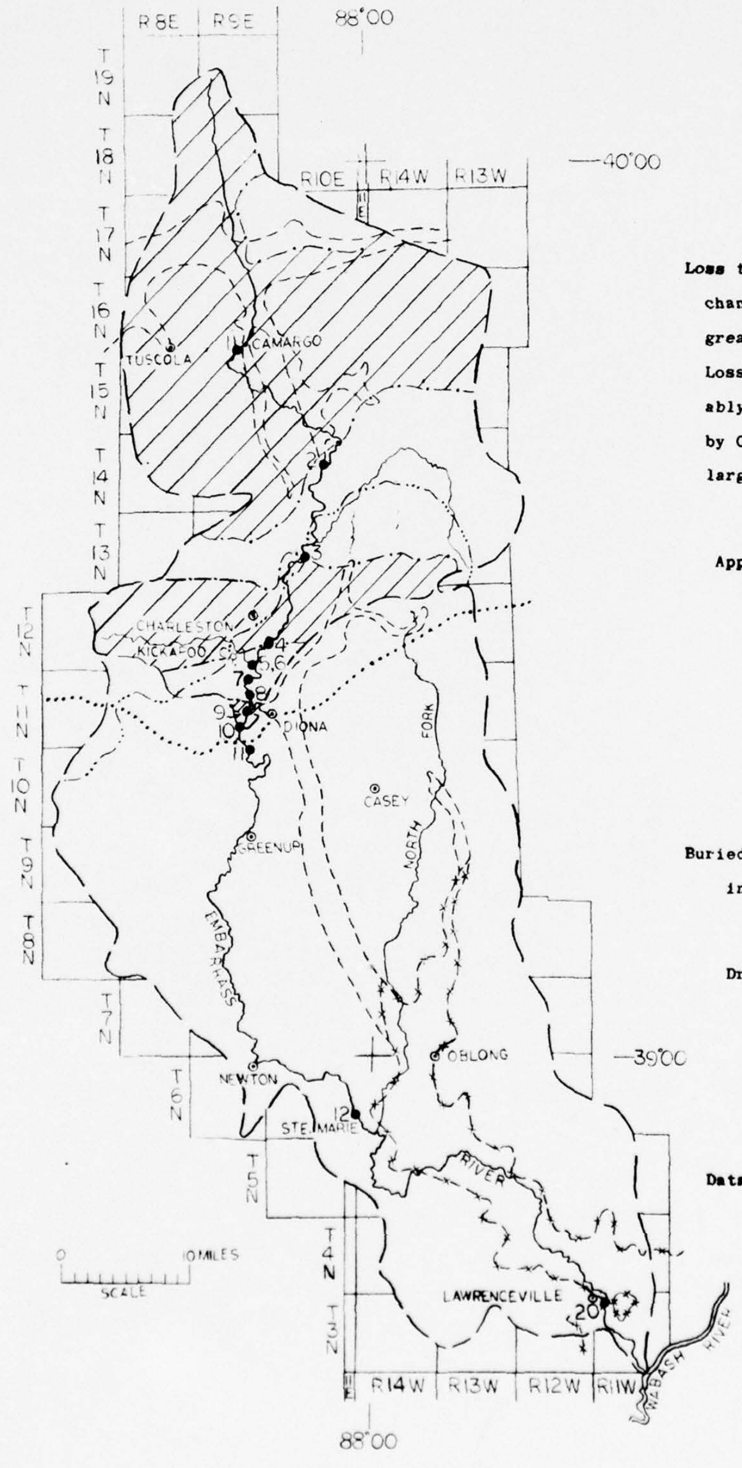

EXPLANATION

Pickup from ground water

Loss to ground water through buried channels and/or evapotranspiration greater than ground-water discharge. Loss in area near Charleston is probably due to use of water from stream by Charleston water department in large part

Approximate boundaries between areas of pickup and loss

Drainage divide

Buried bedrock valley

Buried bedrock valley which coincides in general with present valley

Drainage divide on preglacial bedrock surface

Wisconsin glacial boundary

Data points, numbers refer to table

a/

b/

c/

d/

FIGURE 2.--Stream flow during dry weather is a measure of grou

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EXPLANATION

Pickup from ground water

to ground water through buried
nels and/or evapotranspiration
ter than ground-water discharge.
in area near Charleston is prob-
due to use of water from stream
Charleston water department in
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roximate boundaries between
areas of pickup and loss

Drainage divide

Buried bedrock valley

bedrock valley which coincides
general with present valley

ainage divide on preglacial
bedrock surface

Wisconsin glacial boundary

points, numbers refer to table

during dry weather is a measure of ground-water yield

Embarrass River - Main Stem

Stream-flow measurements and dry-weather yields at approximately 99 percent flow duration at given date and 90 percent flow duration

Map number	Date	Drainage area (sq mi)	99 percent flow duration		90 percent flow duration		Remarks
			Discharge (cfs)	Yield (cfs/sq mi)	Discharge (cfs)	Yield (cfs/sq mi)	
1	10-17-63	185	0	0	0.62	0.0034	Camargo gage[d]
2	10-17-63	517	.1[a]	.0002	7	.013	Oakland gage[b]
3	10-17-63	718	.63[c]	.0009			
4	10-17-63	785	0	0			Riverview dam
5	10-18-63	788	.2[a]	.00025			Mouth of Kickapoo Cr
6	10-18-63	891	1.2[a]	.0014			Including Kickapoo Cr 1 cfs from Charleston sewage plant
7	10-18-63	894	3.03[c]	.0034			
8	10-18-63	908	3.91[c]	.0043			
9	10-18-63	914	3.41[c]	.0034			
10	10-18-63	915	3.52[a]	.0038			Lincoln reservoir dam site
11	10-17-63	918	3.83[c]	.004	15	.017	Diona gage[b]
12	10-18-63	1,513	16.0	.01	32	.021	Ste.Marie gage
20		2,260			79	.035	Lawrenceville gage[b]

a/ Estimated

b/ Discontinued

c/ Miscellaneous measurement

d/ Estimated from short term record

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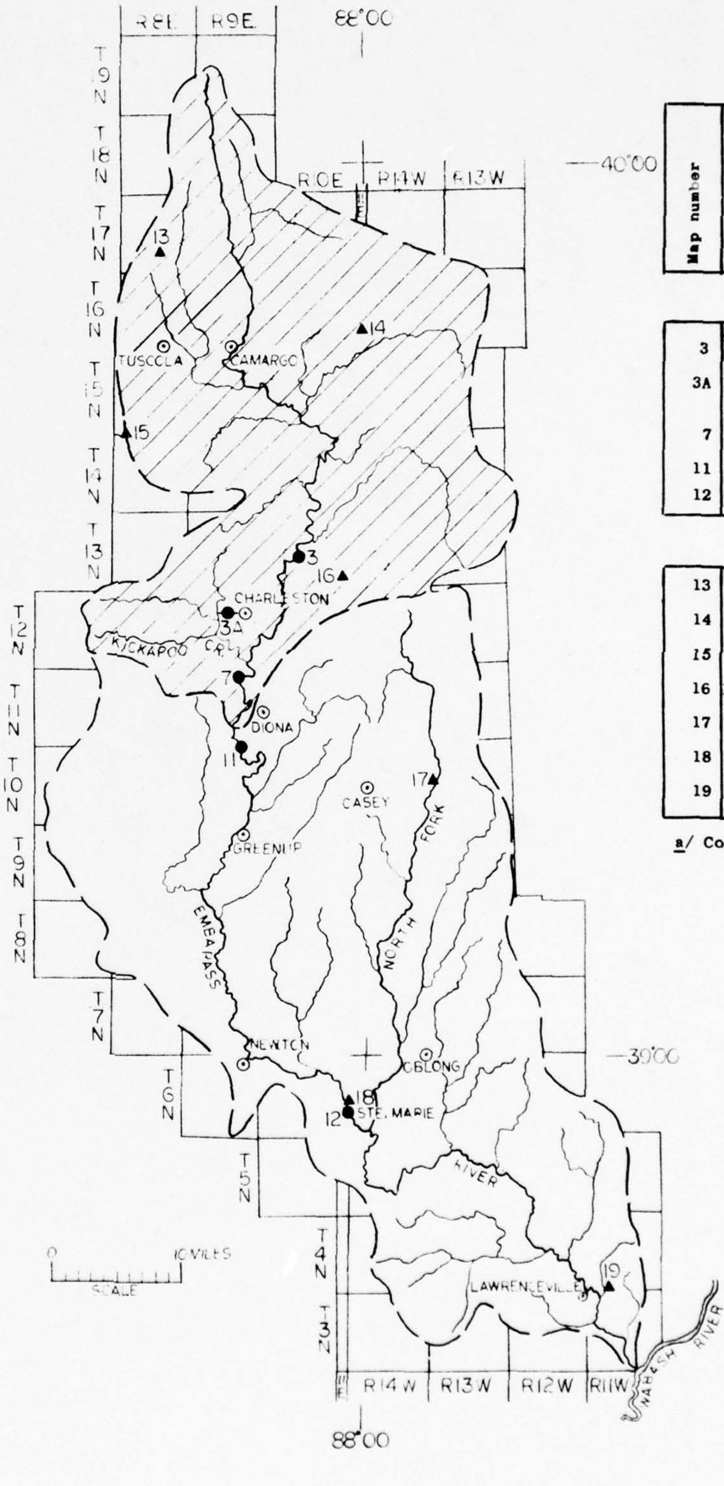

Map number	Date	Temperature (°F)	Bicarbonate
3	10-17-63	59	
3A	10-17-63	69	
7	10-18-63	64	
11	10-17-63	65	
12	10-18-63	64	
13	9-27-57	57	
14	6-22-53	54	
15	6-24-48	56	
16	11-22-60	52	
17	4-30-59	56	
18	9-30-55	56	
19	12-47	56	

a/ Collected and analyz

FIGURE 3.--Chemical quality of surface water during period of dry-weather flow is repre

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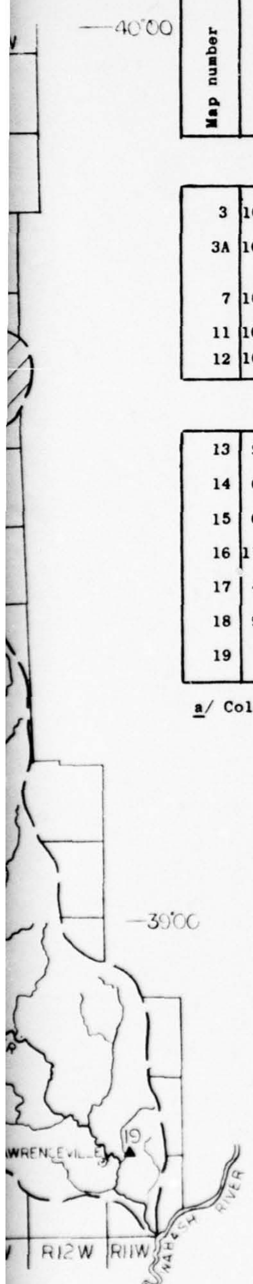

Quality of Water
(results in parts per million except as noted)

Map number	Date	Temperature (°F)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Total dissolved solids	Hardness as $CaCO_3$	Dissolved oxygen		Remarks
									Percent saturated	
Water samples from stream										
3	10-17-63	59	378	40	56	414	355	5.4	53	
3A	10-17-63	69						2.4	27	Tributary of Kickapoo Cr
7	10-18-63	64	407	80	108	624	324	3.8	40	
11	10-17-63	65	370	53	44	452	343	7.8	82	
12	10-18-63	64	336	36	16	360	307	7.2	75	
Water samples from wells[a/]										
13	9-27-57	57	493	1	10	465	240	----	----	188 ft, gravel
14	6-22-53	54	425	2	5	379	281	----	----	58 ft, gravel
15	6-24-48	56	615	1	51	582	290	----	----	128 ft, gravel
16	11-22-60	52	410	70	16	478	414	----	----	42 ft, gravel
17	4-30-59	56	610	1	227	865	173	----	----	132 ft, gravel
18	9-30-55	56	317	21	8	295	253	----	----	54 ft, gravel
19	12-47	56	190	27	7	227	201	----	----	72 ft, gravel

a/ Collected and analyzed by the Illinois State Water Survey

EXPLANATION

3

Water sample from stream
number refers to table

13

Water sample from well,
number refers to table

Drainage divides

Drainage area above
dam site

ring period of dry-weather flow is representative of ground-water quality if stream is not polluted

2

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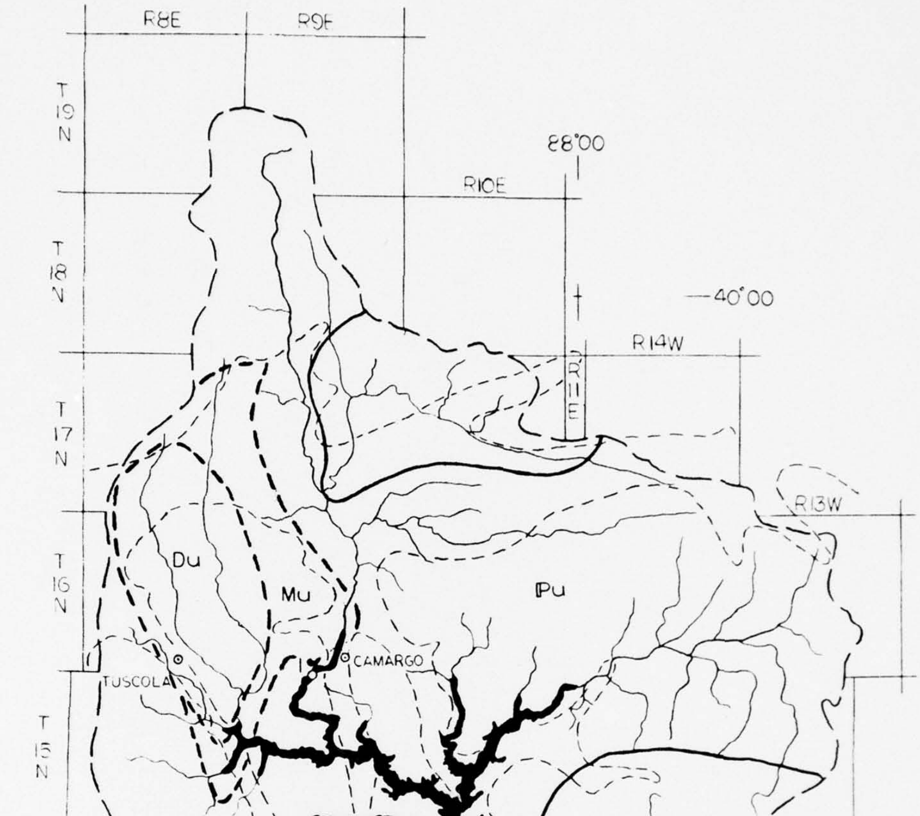

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Approximate b

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Maximum

62

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Buried bedrock

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gravel, also

ground water

Subcrop

Geology after the Illinois State Geological Survey

FIGURE 4 .--Geology and ground-water characteristics at the

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EXPLANATION

Quaternary System "these deposits mantle entire area" Recent and Pleistocene series Predominantly till, sand and gravel	Small yields from till; small to moderate yields from sand and gravel interbedded with till; moderate to large yields possible from sand and gravel in buried bedrock valleys; usually more uniform in chemical quality than water from the bedrock
Pennsylvanian System Pu undifferentiated Predominantly sandstone and shale	Small yields, predominantly from sandstone; chemical quality of the water becomes poorer with depth
Mississippian System Mu undifferentiated Predominantly shale	Not water yielding
Devonian System Du undifferentiated Predominantly dolomite and limestone	Too deep to be considered as source over most of the basin; small to moderate yields, large yields possible where creviced and lying directly beneath Pleistocene deposits; chemical quality becomes poorer with depth

Approximate boundaries between areas of pickup and loss as shown on figure 2

Maximum pool area, elevation 629 feet msl

O[1]
Data point
Number refers to figures 2 and 3

Buried bedrock valley. Areas of possible large yields from sand and gravel, also areas of loss to ground water

Subcrop of bedrock units

l Survey

2

ology and ground-water characteristics at the Lincoln Reservoir site.

TABLE 1 .-- Summary of Ground-Water Hydrogeologic Relation

		Geology, Material, and Water-bearing Properties	Fig.	Availability of Ground Water	Fig.	Quality of Ground Water	Fig	Present Use of Ground Water	Potential Use of Ground Water	Dry-Wea the Emb
Embarrass River Basin		Recent and Pleistocene sand and gravel in preglacial bedrock valley which coincides in general with present valley; large permeability	1	Large supplies; deposits thick and areally extensive; shallow water levels	1	Generally used without treatment for domestic and farm purposes; needs treatment for municipal and industrial purposes; subject to surface contamination; hard to very hard; generally more uniform in quality than water from bedrock aquifers	3, 4	Municipal, industrial, domestic, and farm	Source of additional water for all purposes	Largest flow i
	Reservoir site	Pleistocene sand and gravel in buried bedrock valleys; moderate to large permeability	1, 4	Moderate to large supplies; deposits thick and areally extensive; usually shallow water levels	1, 4	Generally used without treatment for domestic and farm purposes; needs treatment for municipal and industrial purposes; hard to very hard; generally more uniform in quality than water from bedrock aquifers	3, 4	----do----------	Probable source of additional water for all purposes	Does not to dry- flow
		Pleistocene sand and gravel interbedded with till, includes some Recent alluvium; moderate to large permeability	1, 4	Small to moderate supplies; deposits scattered and not areally extensive; usually shallow water levels	1, 4	Generally used without treatment for domestic and farm purposes; needs treatment for municipal and industrial purposes; hard to very hard; generally more uniform in quality than water from bedrock aquifers	3, 4	----do----------	Will increase as rural nonfarm population increases; possible source of additional water for small municipal and small industrial supplies	Dry-weath from m Kickapo southw
		Pleistocene till; small permeability	1, 4	Small supplies from dug wells; shallow water levels	1, 4	Generally used without treatment for domestic and farm purposes; hard to very hard	3, 4	Domestic and farm where no other source	Not important as a source	Contribu weather
		Pennsylvanian chiefly sandstone; small permeability	1, 4	Small supplies; shallow to deep water levels	1, 4	Generally used without treatment for domestic and farm purposes; needs treatment for municipal and industrial purposes; soft to very hard; quality becomes poorer with increasing depth	4	Small municipal, small industrial, domestic, and farm	Will increase as rural nonfarm population increases where sand and gravel deposits missing	Not at s the ba therefo contrib weather
		Mississippian chiefly shale; little or no permeability	1, 4	Not water-yielding	1, 4					
		Devonian chiefly dolomite and limestone; small permeability except where creviced	1, 4	Small to moderate supplies; deep water levels; used only in limited area in upper part of basin; too deep to be considered over most of the basin	1, 4	Generally used without treatment for domestic and farm purposes; needs treatment for municipal and industrial purposes; usually hard to very hard; quality becomes poorer with increasing depth	4	Small municipal, small industrial, domestic, and farm in limited area in upper part of basin	Possible source of additional water where sand and gravel deposits missing	

Hydrogeologic Relationships in the Embarrass River Basin

2

ntial Use of ound Water	Dry-Weather Flow of the Embarrass River	Fig.	Ground-Surface Water Relations	Fig.	Effect of Dam on Ground Water	Remarks
e of addition- water for all rposes	Largest dry-weather flow in basin	2, 4	Largest ground-water pickup in this reach of the stream, chemical quality of water in the stream improved by ground-water discharge during low-flow periods	2	Higher stages during low-flow periods will increase the amount of water in storage in the aquifer; loss of water from reservoir through buried valley may increase dry-weather flow	Study needed to determine the areal extent and potential of these deposits
ble source of litional water r all purposes	Does not contribute to dry-weather flow	2, 4	Above dam site--loss from stream through buried valleys; buried valley at north end of basin removes water from the basin; while the one just upstream of the dam site returns water to the stream in the lower part of the basin	2, 4	Impoundment of water in the reservoir may increase the loss to ground water through the buried valleys especially the one just upstream of the dam site; will increase ground-water pickup in lower part of the basin	Study needed to determine the amount of loss from the reservoir through these buried valleys and whether this loss will be detrimental or beneficial; to determine the areal extent and potential of these deposits
increase as al nonfarm pulation in- ases; possi- source of litional water r small muni- pal and small dustrial sup- ies	Dry-weather flow from mouth of Kickapoo Creek southward	2, 4	Ground-water pickup except where underlain by buried valleys; chemical quality of water improved by ground-water discharge downstream from the mouth of Kickapoo Creek	2, 3, 4	Above dam site--impounding water in reservoir will increase the amount of water in storage in aquifer Below dam site--higher stages during low-flow periods will increase the amount of water in storage in the aquifer	Dissolved oxygen determination indicates that deoxygenation is a problem in Kickapoo Creek below the outflow from Charleston's sewage disposal plant and in the Embarrass River for a short distance downstream from the mouth of Kickapoo Creek during low-flow periods; deoxygenation is not a problem from the Diona gage downstream
important as source	Contributes to dry-weather flow	2	Recharge to sand and gravel deposits, which contribute to ground-water pickup, is through these deposits	2, 4	Probably a slight increase in storage adjacent to reservoir and an increase in recharge to underlying material due to increase in head in reservoir area	
increase as al nonfarm pulation in- ases where d and gravel posits missing	Not at surface in the basin and therefore does not contribute to dry-weather flow	2, 4	Recharge reaches these rocks through overlying unconsolidated deposits and therefore effects surface water only indirectly by intercepting some water which might have been discharged to the stream	2, 4	Probably a slight increase in storage in these rocks in the pool area due to increase in head	At the dam site these rocks are overlain by Recent alluvium and possibly Pleistocene sand and gravel; losses may occur through the unconsolidated material; rocks of Pennsylvanian age are the first encountered beneath the unconsolidated deposits except in a small area in the northwest part of the basin
ble source of litional water re sand and vel deposits ssing						

UNITED STATES
DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY
Room 403
611 N. Park Avenue
Indianapolis, Indiana
46204
December 3, 1963

Colonel V. Roper, District Engineer
U. S. Army Engineer District, Louisville
Corps of Engineers
P. O. Box 59
Louisville, Kentucky

Attention: Mr. Robert Hayes

Dear Colonel Roper:

As per paragraph 3 of my letter dated November 18, 1963 the following brief resume of ground-water conditions in the Clifty Creek basin is submitted at this time in lieu of the full report.

There are no public water supplies within the basin itself but there are three public water supplies located just outside at Columbus, Greensburg, and Hope. Columbus and Hope use ground water, and Greensburg uses both ground-water and surface-water sources. Wells at Columbus pump from sand and gravel aquifers. At the two other places wells pump from sand and gravel and bedrock aquifers.

Wells drilled into bedrock range in depth from about 100 to about 300 feet. The bedrock aquifers usually are limestone. The yields from bedrock aquifers range from less than 20 to more than 100 gpm. Yields generally are higher where limestone rock occupies the topographic highs on the pre-glacial bedrock surface. Water levels generally are within fifty feet of the land surface. The chemical quality of the water is good with total dissolved solids usually less than 400 parts per million. The chemical quality of the water becomes poorer with depth.

Wells drilled into sand and gravel range in depth from about 20 to 150 feet. The yields from sand and gravel aquifers range from about 20 to more than 1,000 gpm. Yields generally are higher in the area at the lower end of the basin near Columbus. Other areas of possible high yields are the buried valleys near Hartsville and Adams above the damsite. Small to moderate yields are possible from minor

outwash deposits scattered throughout the basin. Water levels in these aquifers usually are less than 50 feet below the land surface. The chemical quality of the water generally is good with total dissolved solids usually less than 350 ppm.

There are two buried bedrock valleys in the basin above the damsite. The northernmost one enters the basin north of Greensburg and runs almost due west, passing between Adams to the north and Milford to the south. It leaves the basin a few miles northwest of Milford. On October 21, 1963 a discharge measurement was made in Clifty Creek near Sandusky, north of this buried valley, and another discharge measurement made near Milford, south of this buried valley. The discharge was about 0.2 cfs at the upstream site near Sandusky and about 0.1 cfs at the downstream site near Milford, indicating a loss in this reach of the stream. This loss of water from the stream may be accounted for by evapotranspiration and/or loss to the buried valley which lies between the two sites. Losses to this buried valley would not affect the impoundment of water in the reservoir because it is upstream of the upper end of the maximum pool. The southernmost buried valley enters the basin south of Greensburg and runs almost due west passing between Forest Hill to the south and Hartsville to the north. As it passes Hartsville it curves to the southwest until it coincides with the present channel of Clifty Creek which it follows until it leaves the basin near the mouth of Clifty Creek. Losses can be expected through this buried valley if it is not sealed at the damsite.

On October 21, 1963 there was no flow at the U.S.G.S. gage at Hartsville. The discharge of Clifty Creek near the damsite, downstream from the gage, was about .07 cfs on October 21, 1963. This water was from Fall Fork. Dissolved oxygen at this point was 4.8 ppm or 52 percent saturation. This was the lowest value found in four determinations in the basin. Dissolved oxygen of water from Clifty Creek ranged from the above low figure to a high of 10 ppm or 105 percent saturation.

The discharge of Clifty Creek, about 2 miles upstream from the mouth, was 1.3 cfs on October 21, 1963.

The report on this basin will be forwarded to you as soon as it is completed.

Sincerely,

/s/ Claude M. Roberts

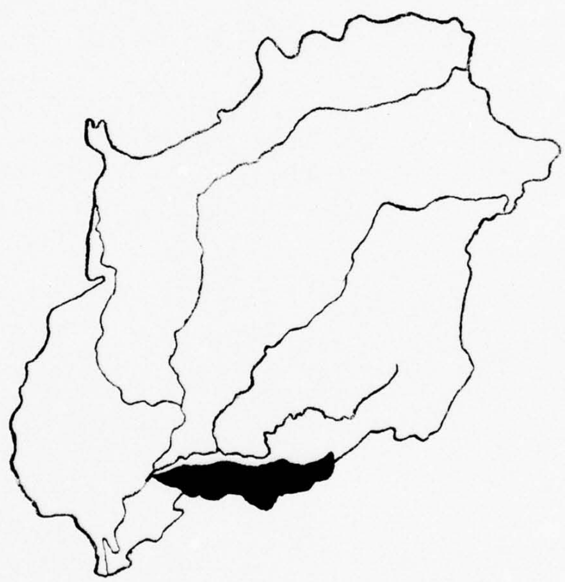
Claude M. Roberts

cc: Division Hydrologist, MCA, St. Louis, Mo.

GROUND WATER APPRAISAL OF THE PATOKA RIVER BASIN AND PATOKA RESERVOIR SITE, INDIANA

by

Frank A. Watkins, Jr.



Prepared by the U. S. Geological Survey

in cooperation with

U. S. Corps of Engineers, Louisville District

November 1963

EXHIBIT F-2

WABASH BASIN COMPREHENSIVE STUDY

GROUND-WATER APPRAISAL OF THE PATOKA RIVER BASIN

AND

PATOKA RESERVOIR SITE, INDIANA

by

Frank A. Watkins, Jr.

PURPOSE

This report appraises the ground-water resources, the ground-surface water relationship, and the chemical quality of ground water in the Patoka River Basin, with emphasis on the availability, adequacy, and useability of the ground water at the Patoka Reservoir site as a part of the study of the Wabash River Basin.

CONCLUSION

Because of the lack of natural subsurface storage and permeable aquifers the only means of obtaining sustained yields greater than 0.6 cfs, which represents the flow of the Patoka River that is exceeded 90 percent of the time, is the construction of a reservoir in the basin to store water and to improve its quality.

This conclusion is based on the following factual observations made in the basin.

1. The dry-weather yield of the basin is small, especially in the upper three-fourths of the basin. The stream is dry on about a 2-year frequency.
2. Bedrocks of Pennsylvanian and Mississippian ages consisting of sandstone, shale, and limestone are sources of only small supplies of groundwater because of their small permeability and lack of secondary openings.
3. Sand and gravel of Pleistocene age, at the lower end of the basin, are the only source of large supplies of ground water in the basin.
4. The chemical quality of the ground water from bedrock is generally good but total dissolved solids can range from less than 200 to more than 2,500 ppm (parts per million). The chemical quality becomes poorer with depth and at depths greater than 300 feet is usually unfit for human consumption.

5. The chemical quality of the ground water from sand and gravel is generally good but total dissolved solids can range from about 200 to more than 600 ppm. The water must be treated for municipal or industrial use.

6. Dissolved oxygen in the water, from the bedrock area of the basin, was low. This is not due to organic pollution but to the fact that the water is recently discharged ground water and flow in the stream is slow, giving little opportunity to pick up oxygen from the air.

7. Dissolved oxygen in the water from the sand and gravel area of the basin, at the State of Indiana water-quality monitor station, was below the minimum value (4 to 5 ppm) used by the State, only once in the period May 1, 1957 to December 30, 1960. Therefore deoxygenation is not a problem in this reach of the stream.

Hydrologic conditions at the proposed reservoir site as related to hydrogeologic conditions are as follows.

1. Precipitation on the Patoka reservoir site and runoff from it are high. Precipitation averages about 44 inches annually and runoff averages about 18 inches annually for the period 1931-60.

2. The dam site is located at the downstream end of an area of ground-water pickup and is near the optimum point for capture of maximum quantities of water and for maximum dilution for quality improvement. The dry weather pickup at this point was about 0.61 c.f.s. on September 25, 1963.

3. Ground water is not a source of large quantities of water in the area of the Patoka reservoir. The rocks in the pool area are of small permeability and yield only small amounts of water. The increased zone of saturation in the contiguous aquifers caused by impoundment of water will have little effect on ground-water yields.
4. Losses to the contiguous aquifers in the pool area will be small due to the small permeability of these rocks. Alluvium at the dam site may be more than 50 feet in thickness and losses through it can be expected if it is not sealed.
5. Buried channels, downstream from the dam, may divert some water from the basin, especially the channel nearest the dam site.

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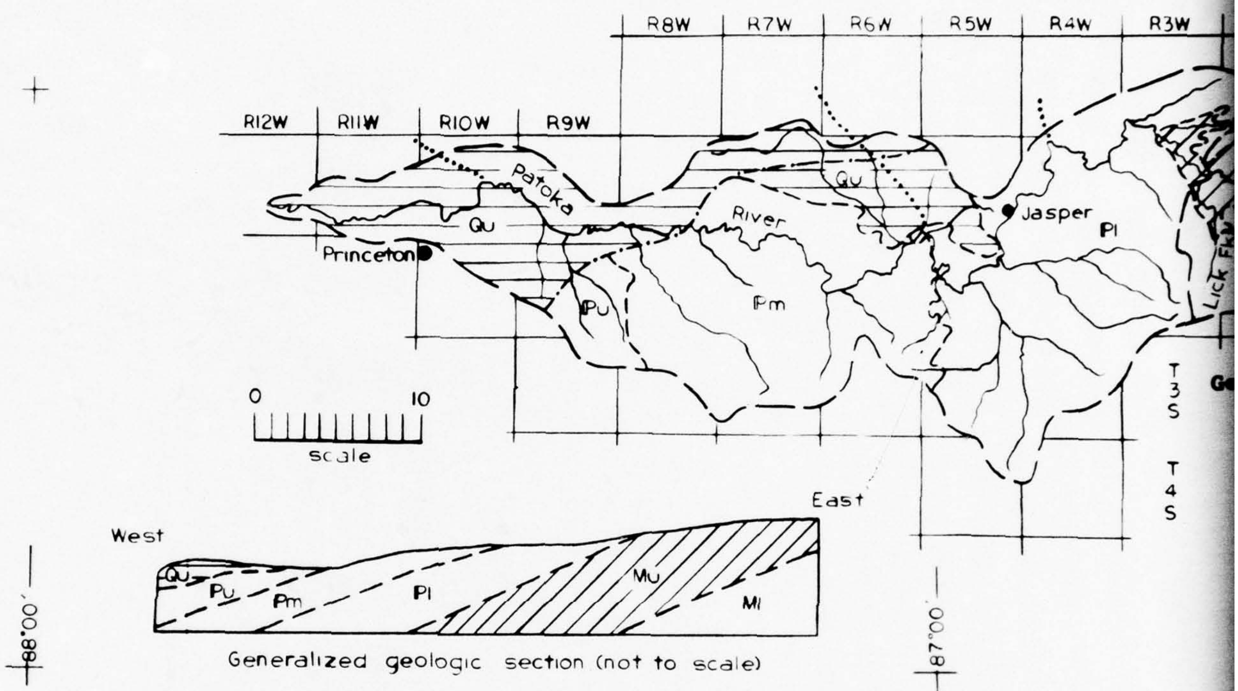

EXPLANATION

Pleistocene Series

Qu

Undifferentiated

Till, sand and gravel, lake sediments, and proglacial lake sediments; source of moderate to large supplies, chiefly from sand and gravel

Pennsylvanian System

IPu IPm IPl

Upper Middle Lower

Sandstone, shale, coal, and limestone source of small supplies chiefly from sandstone

Mississippian System

Mu Ml

Upper

Lower shown on section only

Limestone, sandstone, and shale source of small supplies chiefly from limestone

Approximate locations of buried channels

Geologic boundaries

Illinoian Glacial boundary

Drainage divide

FIGURE 1.--Geology controls availability of

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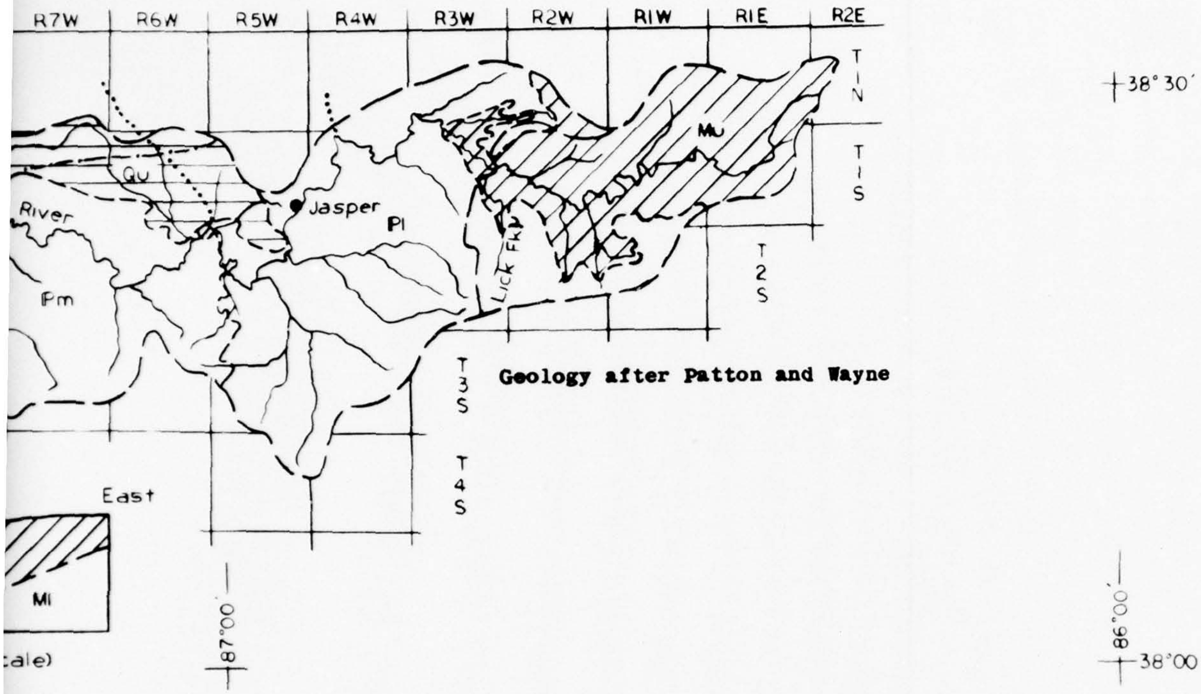

stem

IPl

ower

l, and lime-
ll supplies
one

Mississippian System

Mu — Upper

Ml — Lower shown on section only

Limestone, sandstone, and shale source of small supplies chiefly from limestone

uried channels

ries

oundary

Relative yields and water levels

	Yield (gpm)	Water Levels (feet below land surface)
Recent[a]	< 20 to > 100	< 20
Pleistocene	< 300 to > 300	< 10 to > 40
Upper Pennsylvanian Middle Pennsylvanian Lower Pennsylvanian Upper Mississippian	<1 to >20	< 40 to >100

[a] Not shown on map or section

1 .--Geology controls availability of ground water.

2

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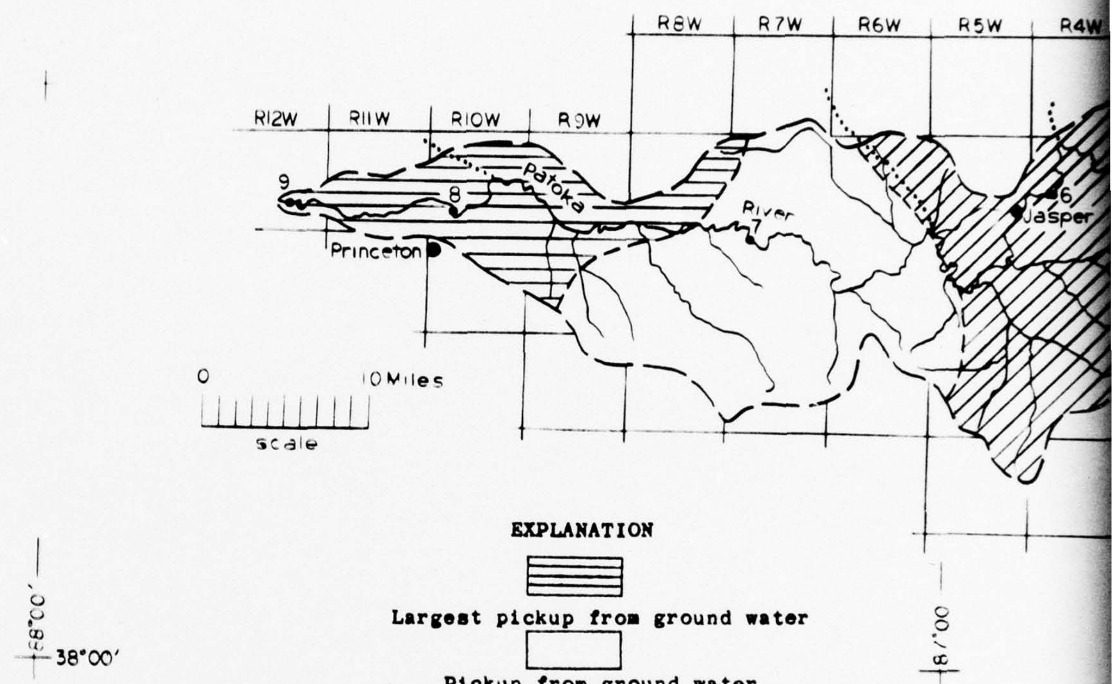

EXPLANATION

Largest pickup from ground water

Pickup from ground water

No apparent pickup or loss, pickup probably balanced by evapotranspiration

Loss to ground water through buried channels and/or evapotranspiration greater than ground water discharge

Approximate location of buried channels

Approximate boundaries between areas of pickup and loss

Drainage divides

Data points, numbers refer to table

FIGURE 2.--Streamflow during dry-weather per

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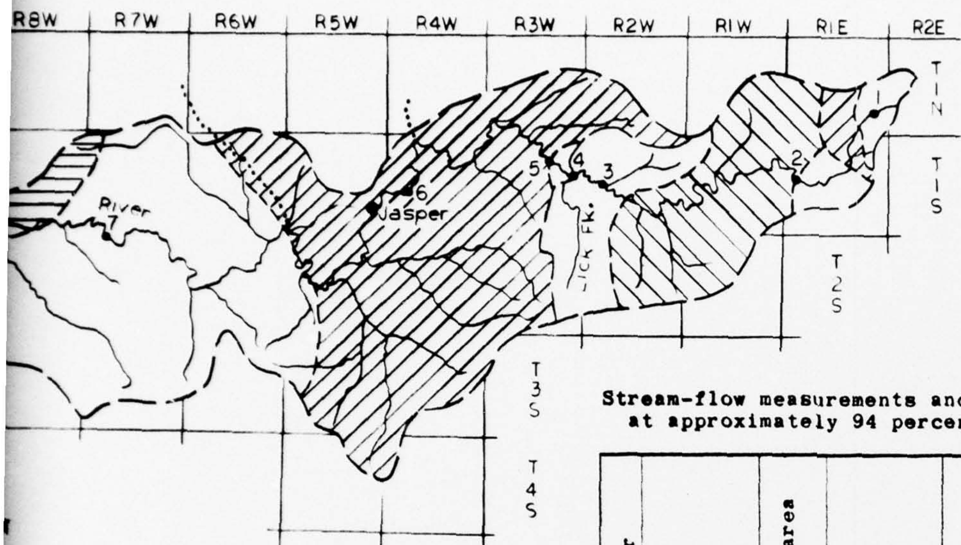

ground water

and water

oss, pickup prob-
otranspiration

rough buried chan-
spiration greater
charge

buried channels

between areas of
loss

vides

refer to table

Stream-flow measurements and dry-weather yields at approximately 94 percent flow duration

Map number	Date	Drainage area (sq mi)	Discharge (cfs)	Yield (cfs/sq mi)	Remarks
1	9-24-63	3	.06 a/	.01	
2	9-24-63	29	.03 a/	.001	
3	9-25-63	135	.53 a/	.004	
4	9-25-63	168	.61 b/	.004	Dam site
5	9-25-63	171	.62	.004	Ellsworth gage
6	9-25-63	257	0	0	Jasper gage
7	9-16-63	603	2.78	.005	Winslow gage
8	9-25-63	815	10.5	.013	Princeton gage
9	9-26-63	860	11.3 b/	.013	

a/ Miscellaneous measurement

b/ Estimated

.--Streamflow during dry-weather periods is a measure of ground-water yield.

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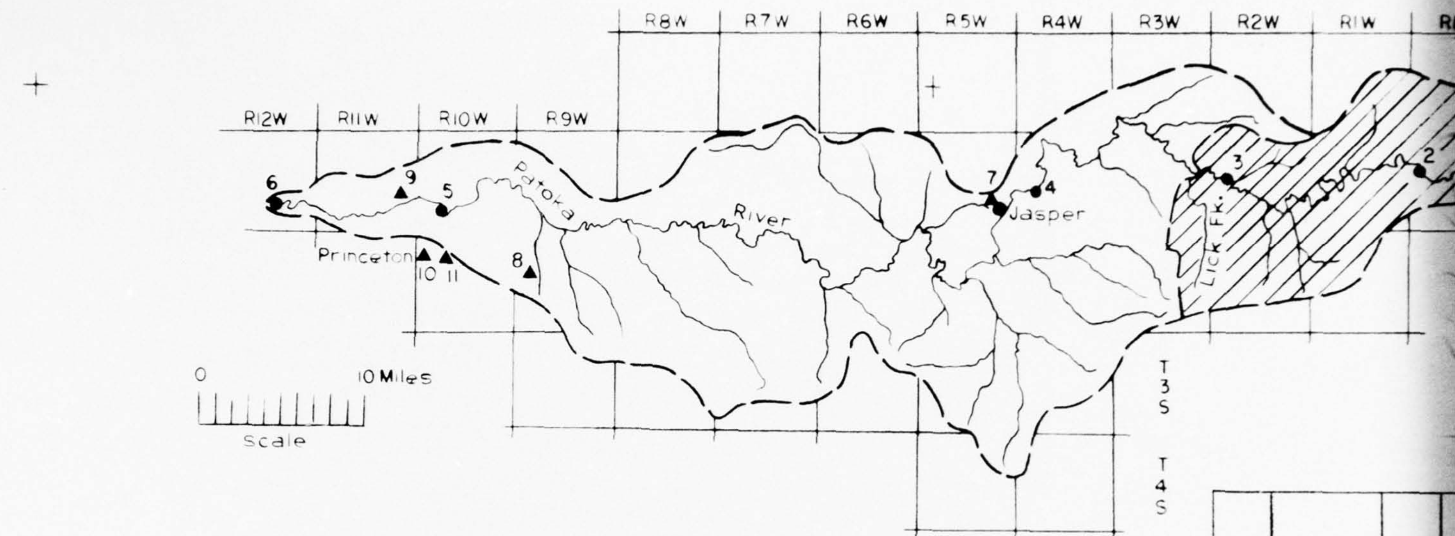

EXPLANATION

Water sample from stream, number refers to table

Water sample from well, number refers to table

Drainage divides

Drainage area above dam site

Map number	Date	Temperature (°F.)
1	9-24-63	61
2	9-24-63	62
3	9-25-63	56
4	9-25-63	61
5	9-25-63	64
6	9-26-63	61
7	11-9-54	59
8	-------	--
9	-------	--
10	4-20-55	58
11	-------	--

a/ Double number

FIGURE 3.--Chemical quality of surface water during period of dry-weather flow is represents

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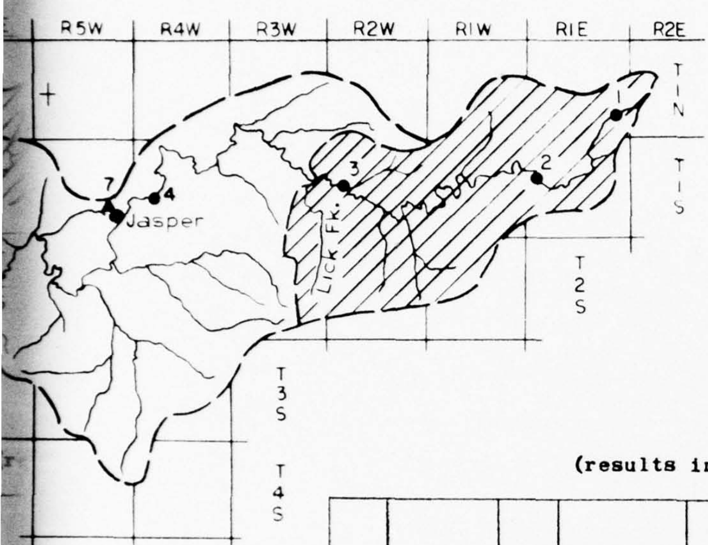

Quality of Water Data
(results in parts per million except as noted)

Map number	Date	Temperature (°F.)	Bicarbonate (HCO_3) a/	Sulfate (SO_4) a/	Chloride (Cl) a/	Total dissolved solids a/	Hardness as $CaCO_3$ a/	Dissolved Oxygen	Dissolved Oxygen: Percent saturated	Remarks
Water samples from stream										
1	9-24-63	61	266	31	44	337	216	----	---	
2	9-24-63	62	271	27	28	309	172	3.6	36	
3	9-25-63	56	208	29	24	252	132	4.8	45	
4	9-25-63	61	134	24	28	193	100	4.3	44	
5	9-25-63	64	100	1,600	120	2,515	1,280	6.9	72	
6	9-26-63	61	205	415	84	886	450	----	---	
Water samples from wells										
7	11-9-54	59	1,260	7	880	2,740	18	----	---	300 ft, rock
8	-------	--	415-570	0-20	6-8	356-516	190-380	----	---	100 ft, rock
9	-------	--	330-415	0-2	1-5	277-357	230-310	----	---	gravel
10	4-20-55	58	415	154	32	607	517	----	---	do
11	-------	--	244-354	25-50	5-10	246-381	240-320	----	---	do

a/ Double numbers indicate range in values from several samples

ing period of dry-weather flow is representative of ground-water quality if stream is not polluted.

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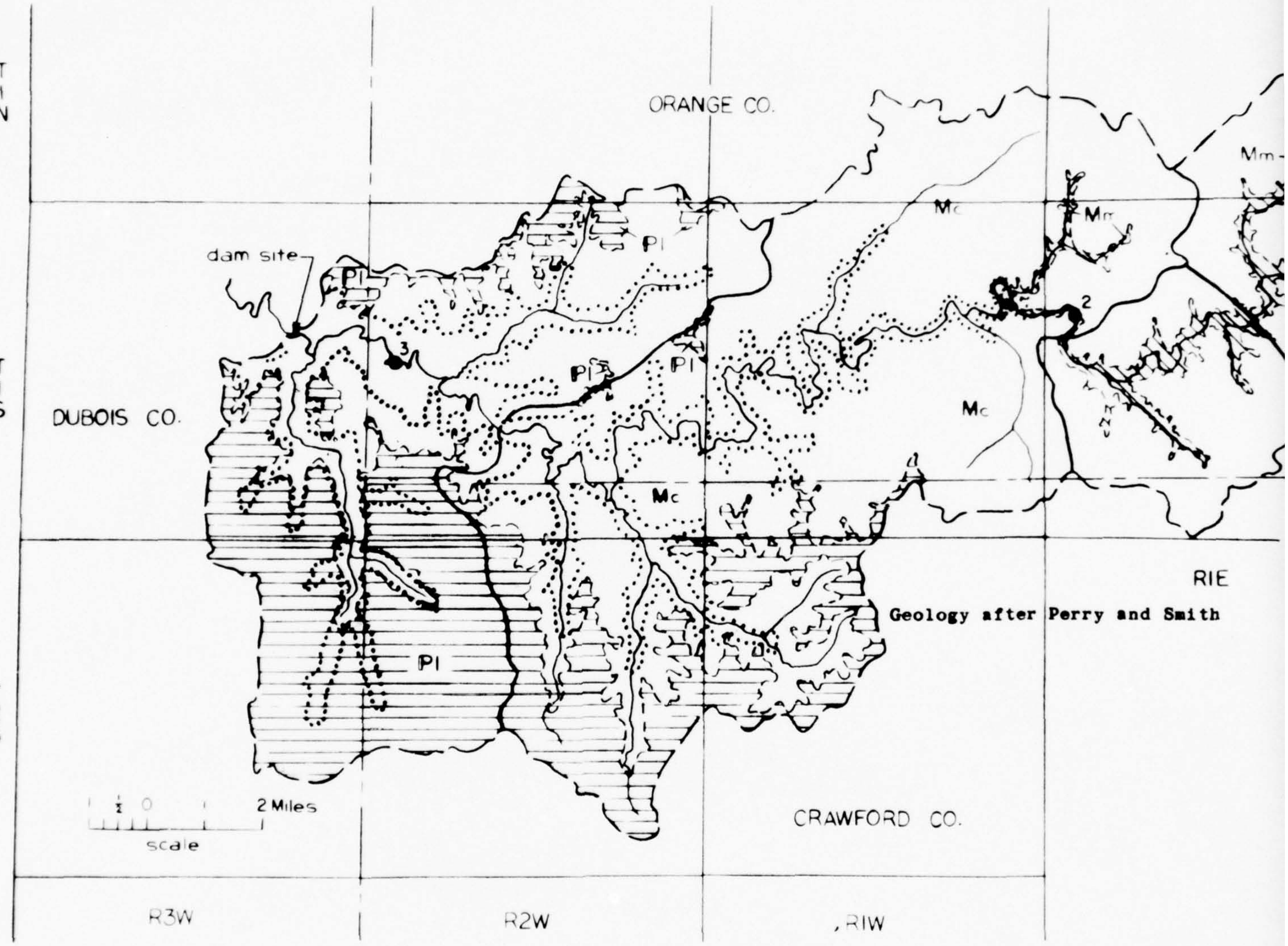

FIGURE 4.--Geology and ground-water characteristics of the bedr

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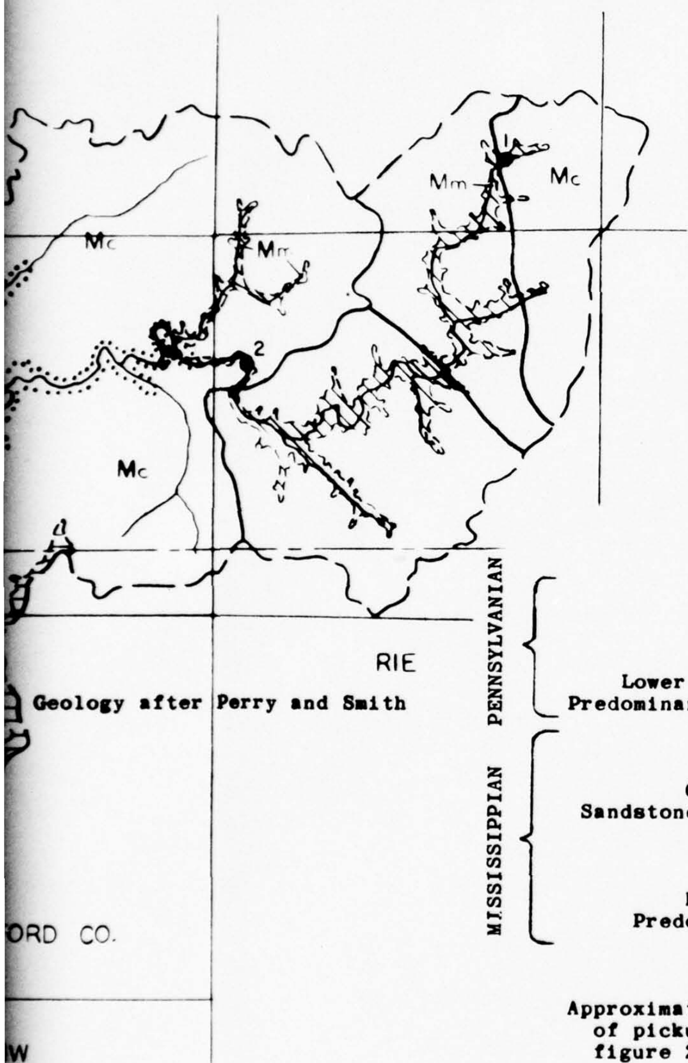


EXPLANATION

PENNSYLVANIAN

Pl
Lower Pennsylvanian Series
Predominantly sandstone and shale

MISSISSIPPIAN

Mc
Chester Series
Sandstone, shale, and limestone

Mm
Meramec Series
Predominantly limestone

Yields small quantities of ground water, generally adequate for domestic and stock supplies. No large yields because of small permeability. Chemical quality becomes poorer with depth; water is usually unfit for human consumption at depths greater than 300 feet

Approximate boundaries between areas of pickup and loss as shown on figure 2

Outline of maximum pool, elevation 550 feet msl

1
Data point
Number refers to figures 2 and 3

und-water characteristics of the bedrock at the Patoka Reservoir site.

2

TABLE 1.--Summary of Ground-Water Hydrogeolog

	Geology, material, and water-bearing properties	Fig.	Availability of Ground Water	Fig.	Quality of Ground Water	Fig.	Present use of Ground Water	Potential use of Ground Water
Patoka River Basin	Recent alluvium, contains sand and some gravel; relative permeability unknown but probably is less than the Pleistocene sand and gravel and more than the bedrock	not shown	May be the source of small to moderate supplies; shallow water levels	not shown	Probably similar to that in the upper part of the rock	not shown	Unknown; but probably small	Unknown; but wil probably remai small; will be covered in large part in the reservoir area by impoun ment of water
Patoka River Basin	Pleistocene sand and gravel; large permeability	1	Moderate to large supplies; shallow water levels	1	Needs treatment for municipal and industrial purposes; subject to contamination; hard to very hard; more uniform quality than water from rock aquifers	3	Domestic and farm, with minor development for municipal and industrial	Source of water for municipal and industrial supplies
Patoka River Basin	Upper Pennsylvanian chiefly sandstone; small permeability; all but small area covered by glacial deposits	1	Small supplies; shallow water levels under the valleys and deep under the hills	1, 2, 4	Generally used without treatment for domestic and farm purposes; becomes highly mineralized with depth; generally unfit for human consumption below 300 feet in depth	3, 4	Domestic and farm primarily; with minor development for small municipal	Not a source of large supplies will increase as rural nonfarm population increases
Patoka River Basin	Middle Pennsylvanian chiefly sandstone; small permeability	1						
Patoka River Basin	Lower Pennsylvanian chiefly sandstone; small permeability	1, 4						
Reservoir Site			Above dam site--not generally a source of water; this rock occupies the tops of the hills and ground-water levels are generally below the bottom of it in the reservoir area	1, 2, 4				
Reservoir Site	Upper Mississippian chiefly limestone; small permeability; few secondary openings	1, 4	Small supplies; shallow water levels under the valleys and deep under the hills	1, 2, 4			Domestic and farm	

TABLE 1.--Summary of Ground-Water Hydrogeologic Relationships in the Patoka River Basin

2

...y of Ground Water	Fig.	Present use of Ground Water	Potential use of Ground Water	Dry-Weather Flow of the Patoka River	Fig.	Ground-Surface Water Relations	Fig.	Effect of Dam... Ground Wate...
...ly similar to ... in the upper ... of the rock	not shown	Unknown; but probably small	Unknown; but will probably remain small; will be covered in large part in the reservoir area by impoundment of water	Dry-weather flow reaches stream through this material	not shown		not shown	See remarks un... Upper Missis... pian
... treatment for ...icipal and in...rial purposes; ...ect to con...ation; hard ...ery hard; more ...orm quality ... water from ... aquifers	3	Domestic and farm, with minor development for municipal and industrial	Source of water for municipal and industrial supplies	Largest dry-weather flow in basin; no flow at times	2	Largest ground-water pickup in this reach of stream; chemical quality and temperature of water in the stream improved by ground-water discharge during low flow periods near the mouth of the Patoka River; near Princeton the chemical quality and temperature of water in stream is poor, probably due to the activities of the coal and petroleum industries upstream; some water may be lost from stream to buried channel	2, 3	Higher stages ... ing low flow periods will ...crease the ... of storage i... aquifer; and ...prove the qu... in the strea... diluting hig... mineralized ... from coal an... petroleum ac...ities
				Not at surface along river	1			
		Domestic and farm primarily; with minor development for small municipal		Usually low dry-weather flow; periods of no flow more frequent than in downstream reach	1, 2	Ground-water pickup during most of the year; source area for most of the contamination from coal and petroleum industries	2 3	
				Below dam site--frequently no dry-weather flow	1, 2	Below dam site--loss from stream in this reach; loss may be due to two buried channels or evapotranspiration may be larger than ground-water discharge	2, 3	Below dam site-- loss to buri... channels may ...crease with i...crease in dis...charge in st... during dry weather
...lly used with ... treatment for ...stic and farm ...poses; becomes ...ly mineralized ... depth; gener...y unfit for hu... consumption ...ow 300 feet in ...th	3, 4		Not a source of large supplies; will increase as rural nonfarm population increases	Above dam site--no contribution to dry-weather flow except through recharge to the underlying rock of Mississippian age	1, 2, 4	Above dam site--wet weather springs found along contact with underlying rock of Mississippian age	2, 4	
		Domestic and farm		Dry-weather flow in some reaches; no flow at times	1, 2, 4	Ground-water pickup in maximum pool reach of stream; springs found along contact between limestones and underlying shales	2, 4	Dam located ne... the optimum point with re...gard to grou... water pickup ... quality impro...ment Impounding wat... in the reser... will cause ground-water levels to ri... in the surro...ing aquifers ... increase the ...mount of wat... in storage b... will have li... effect on gr... water yields

iver Basin

3

Ground-Surface Water Relations	Fig.	Effect of Dam on Ground Water	Remarks
	not shown	See remarks under Upper Mississippian	
est ground-water pickup in this ach of stream; chemical quality and mperature of water in the stream proved by ground-water discharge ring low flow periods near the uth of the Patoka River; near inceton the chemical quality and mperature of water in stream is or, probably due to the activities the coal and petroleum industries stream; some water may be lost from ream to buried channel	2, 3	Higher stages during low flow periods will increase the amount of storage in the aquifer; and improve the quality in the stream by diluting highly mineralized water from coal and petroleum activities	More study needed to map areal extent and potential and to determine the effect of buried channel on stream flows; evidence of petroleum wastes in this reach and contamination from coal mining operations; dissolved oxygen determination indicates that deoxygenation is not a problem at this time
nd-water pickup during most of the ar; source area for most of the ontamination from coal and petroleum dustries	2, 3		
w dam site--loss from stream in is reach; loss may be due to two ried channels or evapotranspiration y be larger than ground-water discharge ve dam site--wet weather springs ound along contact with underlying ock of Mississippian age	2, 3 2, 4	Below dam site--loss to buried channels may increase with increase in discharge in stream during dry weather	More study needed to determine the effect of buried channels on stream flow; evidence of petroleum wastes in reach below dam site; dissolved oxygen determination in this reach indicates that deoxygenation may be a problem
nd-water pickup in maximum pool each of stream; springs found along ontact between limestones and derlying shales	2, 4	Dam located near the optimum point with regard to ground-water pickup and quality improvement Impounding water in the reservoir will cause ground-water levels to rise in the surrounding aquifers and increase the amount of water in storage but will have little effect on ground-water yields	Karst topography is formed on these rocks where they occupy the topographic highs on the bedrock surface but these conditions apparently do not exist within the area of the maximum pool The rocks of Late Mississippian age at the dam site are overlain by Recent alluvium which may be greater than 50 feet in thickness; losses may occur through this material Dissolved oxygen determination indicates that water in this reach is recently discharged ground water

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
1006 WEST LAKE STREET
MINNEAPOLIS, MINNESOTA 55408

In reply refer to:

RB

January 22, 1964

District Engineer
U. S. Army Engineer District
Louisville
P. O. Box 59
Louisville 1, Kentucky

Dear Sir:

This is our Detailed Report on the plan for flood control and allied purposes in the Embarrass River Basin, Illinois. It is submitted for inclusion with your Second Interim Survey Report on water resource development of the Wabash River Basin. This report has been prepared under the authority, and in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). It discusses the anticipated effects of Lincoln Reservoir on the fish and wildlife resources and contains recommendations for their conservation and development.

INTRODUCTION

Pursuant to a resolution adopted May 6, 1958, by the Committee on Public Works of the United States Senate, and other resolutions, the District Engineer, Corps of Engineers, Louisville, Kentucky, has been directed to review prior reports with a view to determining whether improvements in the interest of flood control and water resource development are advisable at this time on the Wabash River and tributaries. In response to the resolution, the Corps of Engineers is currently studying a multiple-purpose project, known as Lincoln Reservoir on the Embarrass River. The purposes for which the project will be constructed are flood control, general recreation, fish and wildlife recreation, water supply, and water quality control.

This report is based on engineering information obtained through correspondence and discussions with the Corps of Engineers, Louisville District. It discusses the anticipated effects of the Lincoln Reservoir on fish and wildlife and contains recommendations for the conservation and development of these resources. Evaluations have been made in accordance with the procedure adopted by the Inter-Agency Committee on Water Resources.

We wish to express our appreciation to the Corps of Engineers, the Illinois Department of Conservation, the Illinois Natural History Survey, the Wabash Valley Interstate Commission, and the Bureau of Outdoor Recreation for the information and assistance they provided.

EXHIBIT F-3

2

DESCRIPTION OF THE AREA

The Embarrass River flows 130 miles south from its source which is just south of Champaign-Urbana in west central Illinois, to its confluence with the Wabash River. It meanders through the gently rolling Champaign Moraine for the first 30 miles and then drops into a steep-walled, V-shaped valley cut through the Wisconsin Till Plain and the Shelbyville Moraine. This steeper V-shaped valley extends for about 45 miles. Tributaries through this reach are of steep gradient, 20 or more feet per mile. This is an area of serious erosion. Near the Coles-Cumberland County line, the river flows into the lower Illinoian Till Plain. From this point to its junction with the Wabash River, the valley is broad, flat-bottomed with rather steep valley walls. The Basin drains a total of 2,500 square miles with 915 square miles lying above the damsite. The project is located in the steep-walled, V-shaped valley that characterizes the stretch through the Shelbyville Moraine.

A stream gauging station existed on the Embarrass River near Oakland for the period 1910 through 1915. Oakland is near the Douglas-Coles County Line and will be within the project area about 20 miles north of the damsite. The average flow during this period of record was 433 c.f.s.; the maximum, 4,860 c.f.s.; and the low, zero. Limited data is available from a stream gauging station near Diona which is near the damsite. The three years for which complete monthly records are available indicate an average flow of 743 c.f.s.; maximum, 14,600 c.f.s.; and minimum, 2.6 c.f.s.

A large amount of silt is carried by the Embarrass River and it rarely is clear. Indicative of this is Lake Charleston, an impoundment on the main stem of the River, which lost 40% of its storage capacity to siltation between 1947 and 1960.

Oil wells are common in the central and southern portion of the basin and oil pollution is a problem. In addition, some domestic and industrial pollution enters from the municipalities through which it flows.

Precipitation varies from 41" in the southern part of the basin to 37" in the north. Mean July temperatures range from 78° in the south to 76° in the north; and mean January temperatures, from 36° in the south to 28° in the north. The growing season is 180 to 190 days long.

Soils of the basin developed from a moderately thick layer of loess. Both forest and prairie soils are present. Prairie soils predominate north of the Coles-Cumberland County line and forest soils, south of this line. Cash grain farming predominates on the prairie soils and grain-livestock farming, on the forest soils.

The Richland County Hunting Area, consisting of leased hunting rights on private land, is in the Basin. In addition, public hunting is permitted on Red Hills State Park, Crawford County State Park, and Jasper County State Park.

The 514-acre Douglas County Conservation Area, of which about 75 acres will be within the project flood pool, also provides public hunting. The Illinois Department of Conservation plans to construct a 70-acre public fishing lake on this area.

The following Public fishing lakes are in the Basin; Lake Charleston, 225 acres; Lincoln Trail Lake, 158 acres; and Red Hills Lake, 40 acres. Lake Charleston is formed by a dam on the mainstem of the Embarrass River near Charleston within the project area. Some public fishing, as well as a fishery research station, is provided at Ridge Lake which lies within the project area.

The population within 25 miles of the project area is about 76,000. Major towns within 25 miles are Charleston (10,500) and Mattoon (19,088). The population within 50 miles is about 448,600. Major towns within this zone include Champaign-Urbana (76,877), Terre Haute (72,500), and Decatur (78,000). Springfield, population 83,271, is 85 miles from the project area; East St. Louis, population 81,712, 120 miles; Peoria, population 103,162, 115 miles; and Chicago and urban fringe, population 5,959,213, 160 miles. State and Federal highways provide good access to the project area.

DESCRIPTION OF THE PROJECT

The damsite is on the Embarrass River about 103 miles above the confluence with the Wabash River.

The 2,400-foot dam will be a rolled, earth-fill structure. It will have a crest elevation of 648 and will be approximately 110 feet in height above the streambed. The spillway will be an uncontrolled, open channel through the left abutment. The width of this channel will be 100 feet. The outlet works, along the toe of the left abutment, will consist of cylindrical, concrete conduit having an outside diameter of 10 feet; three control gates, 4 feet wide by 8 feet high; and a stilling basin. A multiple stage outlet will be incorporated into project plans.

At the minimum pool elevation of 584, the reservoir will inundate 4,310 acres (Table 1). The seasonal pool at elevation 596 will cover 6,760 acres and at full flood-control pool (elevation 620) the surface acreage will be 21,250. The seasonal pool elevation (596) will be attained three years out of four between April 30 and September 15.

Table 1. Lincoln Reservoir

Pool	Elevation (ft. m.s.l.)	Capacity (Ac. Ft.)	Area (Acres)	Stream Miles Inundated
Minimum	584	61,315	4,310	26
Seasonal	596	65,450	6,760	34
Flood Control	629	476,985	21,250	58

FISH AND WILDLIFE RESOURCES

Without-the-Project

Fishery

The Embarrass River furnishes a lightly utilized warm-water sport fishery. Fish species of value for angling include longear sunfish, green sunfish, channel catfish, Kentucky spotted bass, carp, and various suckers. Fish are also caught in the lower reaches of five tributaries.

Fish collections were made in 1962 by the Illinois Department of Conservation, Division of Fisheries, at 20 sampling stations along the Embarrass River. Forage fish represented 82.7% of the total number; game fishes, 15.1% and commercial fish,2.2%. By total weight, commercial species led with 38.1%; game fish, 31.8% and forage fish, 30.1%.

Access to the Embarrass River is limited since all streams flow through private property. This has resulted in heavy fisherman concentrations at bridges. This concentration of fishermen has led, in some instances, to the depletion of fish populations in the immediate vicinity of the access point while other areas are underutilized.

The last reported commercial fishery activity on the Embarrass River was in 1950.

The 86 miles of stream (including 59 miles of Embarrass Main Stem, 9 miles of Kickapoo Creek, 11 miles of the Little Embarrass, and 7 miles of Brushy Fork) that will be within the project area presently supports approximately 3,870 annual fisherman-days use. The 200-acre Charleston Reservoir, which will be inundated by the minimum pool, supports approximately 6,000 annual fisherman-days use. Ridge Lake, a 17.7-acre impoundment operated by the Illinois Natural History Survey, will be inundated by the seasonal pool. Fishing on this lake is by permit only and at restricted times. This fisherman utilization is limited.

Fisherman utilization does not reflect the importance of Ridge Lake to the fishery profession and the advancement of fishery knowledge. Ridge Lake, in Fox Ridge State Park, is an important fisheries research station. The lake and facilities were constructed between 1938 and 1941 by the C.C.C. A number of important fishery studies have been conducted here by the Illinois Natural History Survey and current studies are under way.

Wildlife

Land use in the Embarrass Basin has favored the farm game species -- cottontail rabbit, ring-necked pheasant, and bobwhite quail. Eighty-five per cent of the land of the basin is suitable for crop production. Cash grain farming predominates north of the Shelbyville moraine and a combination of cash grain and livestock agriculture is important south of this line. Cottontail rabbits are found throughout the basin, with the better populations occurring in the southern part, due to more rolling topography with more brushy fencrows and ravines.

Pheasant populations range from high in the northern portions of the basin to absent in the southern portion, with the better populations associated with prairie soils and cash grain farming.

Quail occur throughout the basin. The better populations are found in the southern part of the basin and are associated with the more rolling topography and more brushy fencerows and ravines.

The agricultural lands within the project area support good populations of rabbits and quail and fair pheasant populations in the upper portions of the flood pool, particularly in Douglas County.

Fox squirrels are distributed throughout the wooded portions of the basin. Grey squirrels occur in the more extensive timber areas, particularly in the southern portion of the basin. Both fox squirrels and gray squirrels live within the area of project influence.

Deer range is restricted to the Embarrass Valley and tributaries. A small but growing herd is present.

Night hunting for raccoons is a popular sport among local residents within the project area.

Nesting wood ducks are present and migrants, principally puddle ducks,use the valley moderately. Approximately 86 miles of stream habitat and 200 acres of impoundment habitat are present within the project area. This wetland habitat supports about 1,400 annual waterfowl hunter-days use.

With-the-Project

Fishery

The seasonal pool will result in the loss of 34 miles of stream fishery that supports about 1,500 annual fisherman-days use. Twenty-four miles of stream, supporting about 1,000 annual fisherman-days use, are contained in the flood pool portion of the project.

The 34-mile reach of stream will be replaced by a 6760-acre reservoir formed by the seasonal pool. If properly managed, this reservoir will be capable of supporting 80,400 fisherman-days use annually valued at $80,400.

Conditions for a tailwater fishery, estimated at 10,700 annual fisherman-days use valued at $15,982, will exist in the first mile below the dam if provisions outlined in the fishery plan are implemented.

Charleston Reservoir, a water supply impoundment on the Embarrass River, will be inundated by both the minimum and seasonal pools. As a result, the approximately 6,000 annual fisherman-days use supported by this reservoir will be lost.

The seasonal pool (elevation 596) will inundate the Illinois Natural History Survey operated Ridge Lake in Fox Ridge State Park. This lake supports only

minimal fishing pressure. However, fisherman utilization is not the true criteria of the fishery importance of this installation. This is an important fisheries research station. Not only the lake but a fisheries research laboratory building will be destroyed.

The Illinois Department of Natural Resources plans to construct a 75-acre lake on the 514-acre Douglas County Conservation Area. The project would interfere with these plans.

Wildlife

The reservoir, at seasonal pool elevation, will inundate 6,760 acres of upland game habitat and result in the loss of 1100 annual upland game hunter-days use. The land contained between seasonal pool elevation 590 and the limit of project acquisition will approximate 28,740 acres. Some of this land will be unusable for public hunting since portions will be used for general recreation developments. Portions will be reduced in public hunting value due to intermittent flooding or being contained in narrow strips. Some interference with present plans for wildlife development of the State-owned Douglas County Conservation Area, which is partially in the flood pool, may be anticipated. There will be about 22,000 acres of land that will be capable of supporting 6,400 upland game hunter-days use assuming fee acquisition of all project land and assuming certain areas are made available to the Illinois Department of Conservation through the terms of a General Plan.

FISH AND WILDLIFE PLAN

Fish

Fishery management within the project should be under the jurisdiction of the Illinois Department of Conservation. Management practices would include stocking, pre and post-impoundment population control and fishery surveys.

Access facilities should be sufficient to accomodate the fishing pressure that is anticipated. It is assumed that adequate fisherman access will be provided to the lower portion of the pool in conjunction with access provisions for general recreation. It is particularly important that fisherman access be provided in the area of the upper seasonal pool. Altogether, eight fisherman access sites will be needed - seven at the reservoir and one at the tailwaters.

A zoning plan should be developed to prevent conflicts between reservoir users. This plan should be determined after cooperative studies between this Bureau, the Illinois Department of Conservation and the Corps of Engineers.

Standing timber should be left in selected areas which are to be inundated. These areas provide a varied fish habitat, act as fish concentrators and help fishermen to locate fish concentrations. Angling should be permitted from the reservoir side of the dam and in the area around the tower. These are areas of fish concentration.

A multiple-stage outlet should be incorporated into the project design. The elevations of outlet portals should be determined by future cooperative studies between this Bureau and the Illinois Department of Conservation. Outlets at various levels are necessary in order to maintain desirable water quality in the reservoir and the tailwaters.

Additional land should be acquired to provide public access to the tailwaters. There should be no restrictions on fisherman use of the stilling basin or tailwaters except as required for safety and efficient operation. Adequate flows will be needed below the dam in order to maintain good fish populations.

Ridge Lake, including the fishery laboratory building, will be inundated by Lincoln Reservoir. This facility is operated by the Illinois Natural History Survey. It is an important fishery research station. Replacement of this facility will be necessary.

Every effort should be made to coordinate project plans with the planned construction, by the Illinois Department of Conservation, of a 70-acre public fishing lake on the Douglas County Conservation Area.

The Recommendation Section of this report includes detailed information on methods to implement the Fish and Wildlife Plan.

The fishery plan would require the purchase of about 20 acres of land below the dam adjacent to the tailwater at a cost of about $7,000. Initial cost amortized at 3% interest based on 100-year project life is $221.00. This cost should be borne by the project and considered non-reimbursable.

The plan would also require a 50 car parking lot below the dam at a cost of about $10,000 which would be borne by the project. Initial cost amortized at 3% interest based on 100-year project life is about $316. Annual operation and maintenance costs for this land and fisherman access facility would be about $100 which would be borne by the Illinois Department of Conservation.

The initial development cost of establishing a fish population would approximate $25,000. This would consist of preimpoundment surveys, fish stocking, and fishery rehabilitation. The amortized cost would be about $791.

Annual fishery management operation and maintenance would approximate $5,000. This would consist of such things as fish surveys, limnological investigations and rough fish removal.

Fishery management costs would be borne by the Illinois Department of Conservation.

Cost of replacing the Illinois Natural History Survey operated Fishery Research Center at Ridge Lake which will be destroyed by the project should be borne by the project and be non-reimbursable. This includes (1) a 16-20 acre impoundment (2) a gate valve and outlet large enough to drain the lake in 48 hours (3) a laboratory building sufficient to replace the building that will be destroyed (4) a boat dock in connection with the laboratory.

Table 2. Effects of Lincoln Reservoir Project on Fish and Wildlife Resources. Without and With the Project Assuming Full Implementation of the Plan and Including Costs of the Fish and Wildlife Plan

	Without-the-project		With Project and Fish and Wildlife Plan					
	Acres/ Miles	Man Days of use	Acres/ Miles	Man Days of Use	Increase in Man Days	Value of Increase	Amortized Int.Cost	Ann. O&M
Fishery								
Stream	85	3,825	24	1000	--	--	--	--
Tailwater	1	45	1	10,700	10,655	$15,982	$537.	$100.
Impoundment	217	6,000	6,760	80,400	74,400	$74,400	$791*	$5,000*
Wildlife								
Upland Game	35,500	6,700	22,000	6,400	--	--	$791	$5,000
Waterfowl	86 miles stream 200 acre impoundment	1,400	52 miles stream 6,760 acres	2,000	600	$8,800	--	--

*Does not include cost of replacing the Illinois Natural History Survey Fishery Research Center and lake

Wildlife

In order to compensate for wildlife losses, all project lands should be acquired in fee. The project lands and waters north of State Route 130 and all project lands and waters north of F.A.S. Road 170 where this road crosses Kickapoo Creek should be made available to the Illinois Department of Conservation through the provisions of a General Plan in accordance with Section 3 of the Fish and Wildlife Coordination Act. (See Plate I)

Standing timber should be left uncut in certain areas to be inundated to provide habitat for waterfowl.

Project plans should be coordinated with plans of the Illinois Department of Conservation for the management of the 540-acre Douglas County Conservation Area which will lie partially within the project area.

The land that would be made available to the Illinois Department of Conservation will entail certain initial costs, primarily for hunter parking facilities, access roads and land posting. These costs should be borne by the project, be non-reimbursable, and would total about $25,000. These costs reduced to appropriate annual equivalents are $791.

Costs to be borne by the Illinois Department of Conservation for annual operation and maintenance would be about $5,000 and would include sign replacment, parking lot and access road maintenance, vegetation control, and hunter management.

RECOMMENDATIONS

In view of the existing and potential fish and wildlife resources in the project area and the potential of Lincoln Reservoir to contribute to increased opportunity for the enjoyment of these resources, it is recommended that:

1. The conservation, improvement, and development of fish and wildlife resources be among the purposes for which the project is authorized.

2. Fishery management be under the jurisdiction of the Illinois Department of Conservation.

3. There be a total of at least seven fisherman access sites on the reservoir, each consisting of an access road, boat launching ramp, and parking for at least 40 cars with boat trailers. Four should be located on the lower portion of the seasonal pool and their location should be determined in connection with general recreation areas. The three located in the upper reaches of the seasonal pool should be at (a) Where County Road 170 enters the seasonal pool on the Kickapoo Creek Embayment, (b) Where County Road 17 enters the seasonal pool on the west side (c) At the point on the west side of the seasonal pool opposite the junction of the Embarrass and Little Embarrass Rivers. All launching ramps should be usable to elevation 584'.

4. Standing timber be left in (a) Indian Creek Embayment (b) Kickapoo Creek Embayment (c) Whetstone Creek Embayment (d) Main arm of the reservoir north of Whetstone Creek Embayment.

5. Angling be permitted from the reservoir side of the dam, and the area around the outlet tower.

6. A parking lot of at least 50-car capacity be provided below the dam.

7. That there be no restriction of fisherman use of the stilling basins and tailwaters except as absolutely required for safety and efficient operation.

8. A 1000 x 50 yard strip of land be acquired in-fee on each side of the stream below the dam to provide for public access to the tailwater.

9. The minimum instantaneous release below the dam be equal to normal inflow minus pool evaporation, except that the minimum instantaneous flow never be less than 50 c.f.s.

10. The multiple stage outlet which has been included in project plans have three outlet portals with elevations to be determined after future studies by the Public Health Service, the Illinois Department of Conservation, and this Bureau.

11. The Ridge Lake Fishery Research Station, operated by the Illinois Natural History Survey, be replaced in kind and include:

    (a) A 16-20 acre impoundment with sufficient watershed and runoff to fill the lake 7 or 8 times during a year of normal rainfall.

    (b) A gate-valve and outlet large enough to drain the lake in 48 hours.

    (c) A laboratory building that will provide a similar facility to that now located on Ridge Lake.

    (d) A boat dock connected with the laboratory.

12. Project plans be coordinated with the plans by the Illinois Department of Conservation for the construction of a 70-acre public fishing lake on the Douglas County Conservation area.

13. The entire project area, including the reservoir area up to elevation 634, or the reservoir flood control pool plus 300 ft. horizontally from this pool, be acquired in-fee.

14. All project lands and water north of State Route 130 and all project lands and water north of F.A.S. Road 170 where this road crosses Kickapoo Creek be made available to the Illinois Department of Conservation through the provisions of a General Plan in accordance with Section 3 of the Fish and Wildlife Coordination Act.

15. The approximately $10,900 of the total cost reduced to annual equivalents of the Fish and Wildlife Plan that would be borne by the Illinois Department of Conservation be considered as the local contribution to project costs for fish and wildlife; and all other costs for fish and wildlife be non-reimbursable. This approximately $10,900 would include about $10,100 for annual operation and maintenance and about $800 for initial fishery management.

16. That additional detailed studies of fish and wildlife resources be conducted, as necessary, after the project is authorized, in accordance with Section 2 of the Fish and Wildlife Coordination

Act (48 Stat. 401, as amended, 16 U.S.C. 661 et seq.); and that such reasonable modifications be made in the authorized project facilities as may be agreed upon by the Director of the Bureau of Sport Fisheries and Wildlife and the Chief of Engineers, for the conservation, improvement, and development of these resources.

17. That Federal lands and project waters in the project area be open to public use for hunting and fishing so long as title to the lands and structures remains in the Federal Government, except for sections reserved for safety, efficient operation, or protection of public property.

18. That leases of Federal land in the project area reserve the right of public use of such land for hunting and fishing.

19. That a reservoir zoning plan be developed in connection with overall planning for the reservoir to insure that certain areas (or certain periods) will be available for fishing, hunting, and other wildlife purposes without conflicting uses for general recreation. It is further recommended that the reservoir zoning plan be developed cooperatively with the Bureau of Sport Fisheries and Wildlife, and the Illinois Department of Conservation.

Please notify us of your proposed actions regarding the recommendations. Also, please advise us if there are any material changes or refinements in project plans in order that the report may be revised accordingly.

The cooperation, information, and assistance provided by you and your staff are appreciated.

Sincerely yours,

R W Burwell

R. W. Burwell
Regional Director

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
830 West Broadway
Louisville, Kentucky 40201

ORLED-B

28 February 1964

Mr. R. W. Burwell
Regional Director
Fish and Wildlife Service
Bureau of Sport Fisheries and Wildlife
1006 West Lake Street
Minneapolis, Minnesota 55408

Dear Mr. Burwell:

This is to acknowledge receipt of 200 copies of your report covering Lincoln Reservoir on the Embarrass River, Illinois, and to furnish you our comments on the recommendations contained therein. It is proposed to include a copy of your report and this letter in Appendix F of the Interim Report No. 2 of Wabash River Basin Comprehensive Study. Our comments on each recommendation follow:

Recommendation 1. Concur.

Recommendation 2. Concur, subject to negotiation of mutually-acceptable agreement between Illinois Department of Conservation and Corps of Engineers.

Recommendation 3. Public use access sites will require detailed studies of appropriate development plans during design stage. These studies will give consideration to all public recreation needs that might be served by the project, and will include specific consideration of the sites and developments recommended for fishing recreation. Present consideration of probable scope of public access site development indicates the extent of facilities probably would be at least equal to those recommended.

Recommendation 4. Concur in objective. The specific areas recommended will be favorably considered for standing timber, except as other project needs and purposes at time of detailed planning for general recreation, operation and maintenance, public safety and aesthetics may indicate the need for possible modification in the over-all public interest.

Recommendation 5. This is a matter to be considered at the time of development of detailed plans. However, considerations of public safety make this recommendation questionable whether fishing in these areas, particularly adjacent to the intake structure, can be allowed.

Recommendation 6. Adequate parking space would be provided in detailed plans at downstream site.

Recommendation 7. Concur in objective. Considerations of public safety, however, probably will not allow fishing in the stilling basin itself.

Recommendation 8. Concur. This land would be acquired as a part of the area required for construction, operation and maintenance of permanent structures and would be used for general recreation as well as for fishing.

Recommendation 9. All project purposes must be considered in determining the storage allocations and release rates. Storage allocation in the project plan presented in Interim Report No. 2 for water quality control and water supply would provide a minimum downstream flow of about 25 cubic feet per second. However, if additional downstream benefits associated with increased minimum flow justify additional storage therefor, such revision can be considered during post-authorization planning.

Recommendation 10. Concur.

Recommendation 11. Replacement of this facility as necessary for maintaining its function and capability as affected by the reservoir project is contemplated in the project plan and estimate. As in all Relocation items, the basis for settlement will be a matter for determination by detailed studies and negotiation between the owner and the Government.

Recommendation 12. Concur.

Recommendation 13. Present report plans and estimates are based on fee acquisition of the entire reservoir area, to the limits established by the Joint Policy. In the acquisition process, consideration of taking to reduced limits or lesser estate on any individual tracts would be a matter for detailed real estate studies pursuant to the exception provisions of the Joint Policy.

Recommendation 14. Concur in general objective, for project areas determined available and licensed or leased for fish and wildlife purposes by the Corps of Engineers. Extent of application would be dependent on results of studies for Master Plan of project development and use, and negotiations with the Illinois Department of Conservation during the design and construction of the project.

Recommendation 15. Non-Federal investment and operation and maintenance costs for fish and wildlife have not been included in the project analysis, and fish and wildlife benefits claimed for the project have been reduced accordingly. Therefore, no contribution by the State would be required for reimbursement of project costs in the plan as presented.

ORLED-B
Mr. R. W. Burwell

28 February 1964

Recommendation 16. Concur.

Recommendation 17. Concur, subject to additional proviso at end, as follows: "or as may be determined necessary for other project purposes in consideration of over-all public interest."

Recommendation 18. Would favorably consider to extent practicable. Feasibility would depend upon lease purposes, locations, and other variable factors and would require that determination be made on an individual lease basis.

Recommendation 19. Concur in general objective. Procedures employed in detailed studies, planning and formulation of the Master Plan for development and management of the project area will give consideration to fish and wildlife conservation, enhancement and recreation as well as other public needs and purposes.

Your cooperation and that of your staff in connection with preparation of the subject report is sincerely appreciated.

Very truly yours,

W. ROPER
Colonel, Corps of Engineers
District Engineer

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
1006 WEST LAKE STREET
MINNEAPOLIS 8, MINNESOTA

In reply refer to:

RB

January 16, 1964

District Engineer
U. S. Army Engineer District
Louisville
P. O. Box 59
Louisville 1, Kentucky

Dear Sir:

This is our detailed report on the plan for flood control and allied purposes on Clifty Creek, Indiana. It is submitted for inclusion with your Second Interim Survey Report on water resource development of the Wabash River Basin. The report has been prepared under the authority of, and in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401 as amended; 16 U.S.C. 661 et seq.). It discusses the anticipated effects of Clifty Creek Reservoir on fish and wildlife resources and contains recommendations for the conservation and development of those resources.

INTRODUCTION

Pursuant to authority contained in a Senate Resolution adopted May 6, 1958 and other resolutions, the District Engineer, Corps of Engineers, Louisville, Kentucky, has been directed to review prior reports with a view to determining whether improvements in the interest of flood control and water resource developments are advisable at this time on the Wabash River and tributaries.

The Clifty Creek Reservoir plan will serve the purposes of flood control, fish and wildlife conservation and general recreation.

This report is based on engineering information obtained through correspondence and discussions with you and your staff prior to January, 1964. It discusses the anticipated effects on fish and wildlife resources of the proposed Clifty Creek Reservoir and presents a Fish and Wildlife Plan for integration with the Corps of Engineers' plans for multiple-purpose water resource development in this part of the Wabash River Basin.

Evaluations of the effects of this project on fish and wildlife resources have been made according to the procedure adopted by the Inter-Agency Committee on Water Resources.

We want to express our appreciation to the Corps of Engineers, the Indiana Department of Conservation, the U.S. Public Health Service, and the Bureau of Outdoor Recreation for the information and assistance they provided.

EXHIBIT F-3

DESCRIPTION OF THE AREA

In the project area, Clifty Creek is a medium gradient stream 20 to 40 feet wide. The creek flows through a deep, narrow valley. The flood plain, generally, is less than 1,000 feet wide. The main channel flows through glacial till and gravel or limestone bedrock. Fall Fork Creek joins Clifty Creek at the damsite. This small tributary has developed almost entirely in limestone, which has resulted in a waterfall about 10 feet high. Middle Fork Creek joins Fall Fork Creek in the project area. At the confluence of these two small streams, their combined flood plains have formed a wide, flat-bottomed valley about 3/4 mile square. Other tributaries to Clifty Creek are short, high-gradient, intermittent streams.

The area surrounding the Clifty Creek Reservoir site is gently rolling terrain. Annual rainfall is 40"; annual runoff 14"; and average annual temperature, 51° F. Average stream flows during some months have been as low as 1.4 c.f.s., with several consecutive days of zero flow during some years. The glacial-till soils are moderately well drained and fertile.

No major water resources or recreational developments are near the project area.

At the 1960 census, approximately 1,228,000 people resided within 50 miles of the reservoir site and about 150,000, within a 25-mile radius.

Improved highways form a network around the reservoir site, providing adequate access to the site. Interstate Routes 74 and 65 are less than 20 miles away. U. S. Routes 421, 31, and 50 will serve the project area to some extent. Indiana State Routes 46, 9, 3 and 7 will be of considerable transportation aid. A network of County and Township roads will permit adequate access to the reservoir area.

In the project area, agriculture consists of grain farming, dairy farming and livestock production. The flood plains are cleared and cultivated. Forests are confined to scattered farm woodlots, steep valley sides or lowlands along streams. Industrial development is light in this area, except at Columbus, Indiana. Pond construction in the vicinity has been common and several are managed as fee fishing ponds. A few of the larger ponds cater to recreational boaters.

PLAN OF DEVELOPMENT

The damsite for Clifty Creek Reservoir will be at stream mile 18.4. About 140 square miles of the 200 square-mile Clifty Creek watershed will be above the dam. The dam will consist of a concrete river section with earth embankments extending to each abutment. It will be 7,000 feet long and 88 feet high (elevation 753 m.s.l.). The concrete river section will have a controlled overflow spillway 140 feet long at elevation 717. The

140-foot spillway will be controlled by three tainter gates 40 feet wide by 28 feet high, with the tops of the gates at elevation 745, the flood control pool elevation. Two sluices, 4 feet wide by 6 feet high, through the concrete spillway section with a slide gate near the upstream end of each, will provide the means for regulation of outflow from the reservoir. The outlet works will include a multiple-level outlet for regulating normal storage releases. An earth dike 3,500 feet long and 13 feet high will be constructed across a low point in the valley rim 0.4 mile south of the dam. A 3,000-foot earth levee will be necessary to protect the Village of Hartsville. Table 1 gives data on pool elevations, acreages, and storage capacities. Detailed information on operational schedules is not available at this time.

Lands will be acquired for (1) the damsite, construction areas and permanent structures, (2) the reservoir area up to elevation 748, (3) a minimum of 300 feet horizontally from the flood control pool where the 748 elevation does not provide the area, and (4) 600 acres along the shoreline to meet present and future requirements for outdoor recreation. The total fee acquisition for this project is estimated at 4,300 acres.

Table 1. Clifty Creek Reservoir - Engineering Data

Item	Elevation (ft. m.s.l.)	Storage Cap. (Ac.Ft.)	Area (Acres)	Stream Miles Inundated
Stream bed	665	--	--	--
Minimum Pool	705	7,655	548	5
Seasonal Pool	720	18,515	919	6
Flood Control Pool	705-745	48,553	2,390	8
Total Storage	745	56,208	2,390	8
Land Above Elevation 745		--	1,910	--
Total Land			4,300	--

FISH AND WILDLIFE RESOURCES

Without-the-Project

Fishery Resources

Clifty Creek Reservoir will affect about 9 miles of Clifty Creek. This area supports a moderately utilized warm-water fishery of fair quality. Smallmouth bass, rock bass, channel catfish, flathead catfish, bullheads,

and suckers are caught. Angling occurs mostly during the spring and early summer, since low flows later in the summer inhibit good fishing conditions. Fall Fork Creek is small, with few pools adequate to sustain significant game fish populations. Therefore, fishing pressure is light on the 6.6 miles affected.

On the streams in the project area, annual angler utilization has amounted to 1,020 angler days.

Wildlife Resources

The Clifty Creek flood plain within the project area is about 70 percent cleared and farmed. Wooded valley sides, farm woodlots, and residential areas make up the other 30 percent. Farm game habitat and farm game populations are good. Cottontail rabbits and quail are especially abundant. The 4,300 acres proposed for acquisition currently supports about 360 annual farm-game hunter-days use. The forest game habitat of the project area presently sustains about 390 annual, forest-game hunter-days use, of which most are directed toward fox squirrels and raccoons.

Aquatic furbearers are not abundant, since bedrock banks are not suitable habitat. Beaver were stocked at one time, in an unsuccessful attempt to establish them on Middle Fork Creek. Presently, furbearers are of minor significance as a resource of the area.

Waterfowl hunting depends on locally produced birds, mostly wood ducks, and consists of jump shooting along streams. It is estimated that about 25 waterfowl hunting trips take place in the project area annually.

The 4,300-acre project area supports approximately 750 upland-game and 25 waterfowl hunter-days use annually.

With-the-Project

Fishery

The Clifty Creek Reservoir seasonal pool will inundate 5.8 miles of Clifty Creek and 3.3 miles of Fall Fork Creek. To some degree, the 2.1 miles of Clifty Creek and 3.3 miles of Fall Fork Creek above the seasonal pool will be affected and the first mile of Clifty Creek below the dam will be drastically changed.

Approximately 9 miles of stream fishery habitat will be replaced by a 919-acre seasonal pool, which will be fairly stable from May through August and drawn down to a 548-acre minimum pool beginning in September. Although firm information on reservoir operation is not available at this time, it is assumed that the above situation will prevail in most years.

The upper reaches of Clifty Creek and Fall Fork Creek (2.1 and 3.3 miles, respectively) will suffer some adverse effects from occasional inundation, but certain advantages of proximity to the reservoir fishery will tend to offset such effects. Overall angler use is expected to remain unchanged.

During the major fishing season, reservoir operation and discharges, based on stream inflow minus evaporation, could result in unsatisfactory fish habitat in the tailwater.

Wildlife

The seasonal pool of Clifty Creek Reservoir will inundate 919 acres of upland wildlife habitat. Approximately 70 percent, or 643 acres, is productive for cottontail rabbits and bobwhite quail. Hunting for these species is relatively heavy in this area. However, the territory surrounding the project area supports similar game populations and hunting.

The remaining 276 acres within the seasonal pool is forest game habitat. Fox squirrels and raccoons are the major game species of the wooded areas and provide hunting opportunities approximately equal to the farm-game complex. In particular, raccoons are especially abundant and could withstand additional hunting pressure, though night hunting for them already is popular.

Total upland game losses will amount to 160 hunter-days use annually. Frequent flooding of areas above the seasonal pool will result in some adverse effects on upland game habitat. Clearing the perimeter of the seasonal pool to elevation 722 will result in additional wildlife losses.

Approximately 600 acres outside the flood pool will be acquired and developed for general recreation. The location, degree of development, and administering agency have not been determined. However, it is anticipated that hunting will not be permitted in certain of the high use areas and some loss of hunter-day use will occur.

Approximately 4,300 acres of land will be acquired in fee. Excluding the above 600 acres of general recreation land, 2,781 acres will lie above the seasonal pool. This land, in general, consists of (1) severely dissected, steep, narrow strips adjacent to the seasonal pool and (2) small parcels in the upstream portions of the flood pool. None of these areas is suitable for intensive wildlife management. However, they could continue to provide upland public hunting under an extensive management program.

Approximately 8 miles of stream-type waterfowl habitat, currently supporting 25 annual waterfowl hunter-days use and a fair amount of wood duck production, will be inundated by the 919-acre seasonal pool. During the fall migration and hunting season, this pool will be drawn down to the 548-acre minimum pool. Normal clearing operations will decrease the attractiveness of both pools to waterfowl.

FISH AND WILDLIFE PLAN

Fish

Fishery management within the project should be under the jurisdiction of the Indiana Department of Conservation. Management practices would include stocking, fish population control, pre- and post-impoundment surveys, possible stream rehabilitation above the dam, and marking of zone boundaries.

Access facilities should be sufficient to accommodate the fishing pressure that is anticipated. It is assumed that adequate fisherman access will be provided to the reservoir in conjunction with access provisions for general recreation. Supplemental shore-angler access should be provided by allowing existing roads, scheduled for abandonment, to remain open for public use. Altogether, five fisherman access sites will be needed -- four at the reservoir and one at the tailwaters.

Standing timber should be left in selected areas which are to be inundated. These areas provide a varied fish habitat, act as fish concentrators and help fishermen to locate fish concentrations.

A zoning plan should be established to prevent conflicts between reservoir users. This plan should be developed after cooperative studies between this Bureau, the Indiana Department of Conservation and the Corps of Engineers.

A multiple-stage outlet with at least two portals should be incorporated into the project designs. Further studies may indicate the need for a third portal. Outlets at various levels are necessary in order to maintain desirable water quality in the reservoir and the tailwaters.

Additional land should be acquired to provide public access to the tail-waters. There should be no restrictions on fisherman use of the stilling basin or tailwaters except as required for safety and efficient operation. Adequate flows will be needed below the dam in order to maintain good fish populations.

The Fishery Plan would require the purchase of about 10 acres of land below the dam and adjacent to the tailwater. The value of land in this area is estimated to be about $150 per acre. This would result in an initial cost of $1,500, or an average annual equivalent of $48 (amortization over 100-year project life at 3 percent interest). The acquisition and development of this 10 acres should be a project cost.

The initial cost of development of the 919-acre reservoir fishery would amount to approximately $10,000, or $317 annually, (amortized over the 100-year project life at 3 percent interest). These initial activities

would consist of pre-impoundment surveys, zone boundary markings, and fish stocking to establish a population complex designed to provide the maximum productive potential and highest quality fishery possible.

Annual fishery management operation and maintenance costs for the reservoir and tailwaters would be approximately $3,000. This would cover remedial stocking, routine fishery surveys, limnological investigations, certain access-area upkeep, fish population control, and law enforcement activities. Both the initial and annual fishery management cost would be borne by the Indiana Department of Conservation.

With the Fishery Plan in operation, Clifty Creek Reservoir would support approximately 18,850 angler-days use valued at $18,850, while the tailwater fishery would sustain about 4,000 angler-days use annually, valued at $8,000. The 5.4 miles of Clifty Creek and Fall Fork Creek would continue to support about 275 angler-days use annually, valued at $275. Considering the stream fishery losses of about 750 angler-days use annually, the overall net increase in angling opportunity resulting from Clifty Creek Reservoir would be approximately 22,100 annual angler days, valued at $25,100.

Wildlife

Except for the parcels of general recreation land developed for intensive recreational use, all project lands above the seasonal pool should be available for free public hunting under the terms of a Fish and Wildlife General Plan. Wildlife management would be extensive in nature, including posting, habitat development, and law enforcement.

After the project has been constructed and waterfowl habits observed, it should be determined whether a portion of the minimum pool should be designated a seasonal, non-shooting waterfowl refuge under the control of the Indiana Department of Conservation, Division of Fish and Game. Other wildlife management measures would consist of the placement of nesting structures and allowing all timber in the seasonal pool to remain uncut north of relocated State Route 46.

All Federally owned land should be open to free public access and hunting. All public roads scheduled for abandonment, which enter the project area, should remain open to public use for hunter access.

The Wildlife Plan would involve no initial separable costs. Upland game and waterfowl management annual costs would be minor and would be borne by the Indiana Department of Conservation, Division of Fish and Game.

With the Wildlife Plan in operation, the Clifty Creek Reservoir area would sustain approximately 590 man-days use of upland-game hunting annually valued at $1,200 and 125 waterfowl-hunter days use annually valued at $375.

The project would result in a net increase of about 100 waterfowl hunter-days use annually valued at $325. However, there would be an uncompensated upland wildlife loss of 919 acres of habitat, sustaining 160 hunter-days use annually.

Table 2. Effects of Clifty Creek Reservoir on Fish and Wildlife Resources - Without and With the Projects and Costs of Fish and Wildlife Plan (Assuming Full Implementation of the Plan)

	Without Project		With Project and Fish and Wildlife Plan					
	Area	Man Days of Use	Area	Man Days of Use	Increase in Man Days	Value of Increase	Amortized Initial Cost*	Annual Cost (O.&M.)
FISHERY								
Stream	15.5 mi.	1,020	5.4 mi.	275	--	--		
Tail-water			1.0 mi.	4,000	4,000	$ 6,980	$ 48 1/	$ 100
Impound-ment	--	--	919 acres	18,850	18,850	$18,850	$317 2/	$3,000
WILDLIFE								
Upland Game	4,300 acres	750						
Season-al Pool			919 acres	-160 4/	--	--	--	--
Other Project Lands			2,800 acres 3/	590	--	--	--	--
Waterfowl	113 acres	25	548 acres	125	100	$ 325	--	--

* Init. costs amort. over 100 yr proj life at 3.0% int (amort.factor - .03165)
1/ Amort.cost ($1,500) of 10 ac.below the dam for tailwater access.
2/ Amort.init.cost ($10,000) of development of res.fishery(Ind.Dept.Cons.).
3/ This acreage does not incl.the 600 acres planned for gen.recrea.development.
4/ This is wildlife loss for which no compensation measures are planned at this proj. Compensation may be requested later within the framework of the Wabash River Basin Comp. Study.

RECOMMENDATIONS

In view of the existing and potential fish and wildlife resources in the project area and to provide for the protection and development of these resources, it is recommended that:

1. The conservation, improvement, and development of fish and wildlife resources be among the purposes for which the project is authorized.

2. Project lands and waters be licensed to the Indiana Department of Conservation under the terms of a Fish and Wildlife General Plan in accordance with Section 3 of the Fish and Wildlife Coordination Act.

3. About 10 acres of additional land adjacent to the tailwater be acquired and developed at project cost for angler access.

4. A 10-car parking lot and access road be provided for each side of the tailwater channel. It is further recommended that public fishing be permitted in the tailwater up to the opening of the outlet works.

5. A multiple-level outlet facility be incorporated in the structure with two portals with invert elevations of 700 and 715. This facility should be operated to result in minimum instantaneous flows in the tailwater of at least 20 c.f.s.

6. Four reservoir angling and boating access sites be provided. Each should have access road, parking for 20 cars with boat trailers, and a launching ramp down to elevation 705.

7. Roads, scheduled to be abandoned, which enter the project area be left open for hunter and angler use.

8. Public fishing be permitted from the reservoir side of the dam and in the area around the outlet structure.

9. Flooded standing timber in the seasonal pool north of relocated State Route 46 not be cleared.

10. That additional detailed studies of fish and wildlife resources be conducted, as necessary, after the project is authorized, in accordance with Section 2 of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.); and that such reasonable modifications be made in the authorized project facilities as may be agreed upon by the Director of the Bureau of Sport Fisheries and Wildlife and the Chief of Engineers, for the conservation, improvement, and development of these resources.

11. That Federal lands and project waters in the project area be open to public use for hunting and fishing so long as title to the lands and structures remains in the Federal Government, except for sections reserved for safety, efficient operation, or protection of public property.

12. That leases of Federal land in the project area reserve the right of public use of such land for hunting and fishing.

13. That all lands necessary for carrying out the various purposes of the project be acquired in accordance with the provisions of the Joint Policy of the Departments of the Interior and of the Army relative to reservoir project lands of February 16, 1962 and that flowage easements be acquired only on those lands found not to have substantial value for recreation or fish and wildlife purposes.

14. That a reservoir zoning plan be developed in connection with overall planning for the reservoir to insure that certain areas (or certain periods) will be available for fishing, hunting, and other wildlife purposes without conflicting uses for general recreation. It is further recommended that the reservoir zoning plan be developed co-operatively by the agency expected to administer the reservoir, the Bureau of Sport Fisheries and Wildlife, and the Indiana Department of Conservation.

Please notify us of your proposed actions regarding the recommendations. Also, please advise us if there are any material changes or refinements in project plans in order that the report may be revised accordingly.

The cooperation, information and assistance provided by you and your staff are greatly appreciated.

Sincerely yours,

W. P. Schaefer

W. P. Schaefer
Acting Regional Director

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
830 West Broadway
Louisville, Kentucky 40201

ORLED-B

28 February 1964

Mr. R. W. Burwell
Regional Director
Fish and Wildlife Service
Bureau of Sport Fisheries and Wildlife
1006 West Lake Street
Minneapolis, Minnesota 55408

Dear Mr. Burwell:

This is to furnish you our comments and proposals relative to the recommendations contained in your report covering Clifty Creek Reservoir project. A copy of this letter will be included with your report in Appendix F of Interim Report No. 2, Wabash River Basin Comprehensive Study. Our comments on each of your recommendations are as follows:

Recommendation 1. Concur.

Recommendation 2. Concur in general objective for project areas determined available and licensed or leased for fish and wildlife purposes by the Corps of Engineers. Extent of application would be dependent on results of studies for Master Plan of project development and use, and negotiations with the Indiana Department of Conservation, during the design and construction of the project.

Recommendation 3. Concur. Included in project plan. No need to stipulate for Fish and Wildlife purposes only. Land would be acquired and used for Construction, General Recreation and other project needs as well as for fishing.

Recommendation 4. Concur in need for adequate parking and access to both sides. Tailwater development would include facilities for picnicking, potable water, sanitary, etc. for use as a general recreation area. Location and design of facilities will depend on detailed studies of needs, lands required for project construction and operation and maintenance, public safety and other considerations. Concur in public fishing as close to outlet structure as public safety will allow.

Recommendation 5. Multiple-level outlet facility would be included in design of outlet structure. Because of limited storage capability, provision of 20 c.f.s. minimum release will require detailed evaluation with respect to benefits affected thereby, including flood control, water quality control and recreation benefits. Detailed study required for determination of the minimum release would be undertaken as a part of post-authorization planning.

Recommendation 6. It is expected that facilities for public access provided would at least equal those recommended. Number, location and extent of facilities at the public access sites will require detailed studies for appropriate development plans during design stages, as a part of studies of over-all recreational needs, including fishing and hunting.

Recommendation 7. Concur in objective to make use of existing roads for access to the water, although it is not always possible, practical or desirable to lease all such roads available for public use. Good management practice in the over-all public interest generally is to provide for access at controlled locations, so that adequate policing, maintenance, sanitation, etc., can be provided. Reservoir management plans could consider operation of some reservoir area roads on a seasonal basis. Use of existing roads could be given detailed consideration in Master Plan studies, including fish and wildlife area development and management plans.

Recommendation 8. This is a matter to be considered at time of development of detailed plans. However, considerations of public safety make it questionable whether fishing in these areas, particularly adjacent to the intake structure can be allowed.

Recommendation 9. Concur in objective. Accomplishment would be subject to consideration of all project purposes, effects and development of zoning plan.

Recommendation 10. Concur.

Recommendation 11. Concur, subject to additional proviso at end, as follows: "or as may be determined necessary for other project purposes in consideration of over-all public interest."

Recommendation 12. Would favorably consider to extent practicable. Feasibility would depend upon lease purposes, locations, and other variable factors and would require that determination be made on an individual lease basis.

Recommendation 13. Concur. Present report plans and estimates are based on fee acquisition of the entire reservoir area, to the limits established by the Joint Policy. In the acquisition process, consideration of taking to reduced limits or lesser estate on any individual tracts would be a matter for detailed real estate studies pursuant to the exception provisions of the Joint Policy.

ORLED-B
Mr. R. W. Burwell

28 February 1964

Recommendation 14. Concur in general objective. Procedures employed in detailed studies, planning and formulation of the Master Plan for development and management of the project area will give full consideration, along with other public needs and purposes, to fish and wildlife conservation, enhancement and recreation.

Your cooperation and that of your staff in connection with preparation of the subject report is sincerely appreciated.

Very truly yours,

W. ROPER
Colonel, Corps of Engineers
District Engineer

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
1006 WEST LAKE STREET
MINNEAPOLIS, MINNESOTA 55408

In reply refer to:

RB

January 22, 1964

District Engineer
U. S. Army Engineer District
Louisville
P. O. Box 59
Louisville 1, Kentucky

Dear Sir:

This is our detailed report on the plan for flood control and allied purposes in the Patoka River Basin, Indiana. It is submitted for inclusion with your Second Interim Survey Report on water resource development of the Wabash River Basin. The report has been prepared under the authority, and in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). It discusses the anticipated effects of Patoka Reservoir on fish and wildlife resources and contains recommendations for their conservation and development.

INTRODUCTION

Pursuant to authority contained in a Senate Resolution dated May 6, 1958, the District Engineer, U.S. Army Engineer District, Louisville, Kentucky, has been directed to review prior reports with a view to determining whether improvements in the interest of flood control and water resource development are advisable at this time on the Wabash River and its tributaries.

This report is based on engineering information obtained through correspondence and discussions with you and your staff prior to January, 1964. It discusses the expected effects on fish and wildlife of the unauthorized Patoka Reservoir, which will be constructed for flood control, general recreation, fish and wildlife, and water quality control. It presents a Fish and Wildlife Plan for integration with the Corps of Engineers' multiple-purpose water resource development plans for the Wabash River Basin. Evaluations of the effects of this project on fish and wildlife resources have been made in accordance with the procedure adopted by the Inter-Agency Committee on Water Resources.

DESCRIPTION OF THE AREA

In the vicinity of the project, the Patoka River is a sluggish, meandering stream 20 to 35 feet wide. The tributaries, Young's Creek, Little Patoka River, Fleming Creek, Painter Creek, and Lick Fork Creek, are small, high gradient, short streams. The Patoka River's main channel is about 8 feet deep, with steep, relatively unvegetated, sides. Average stream flows at

Jasper have fluctuated from a high of 3,565 c.f.s. to a low of 4.8 c.f.s. During most years, stream flow virtually ceases for several consecutive days. The flood plain of the Patoka River varies in width from 1,000 feet to 8,000 feet in the reservoir area. The surrounding terrain is steep and partially wooded.

The reservoir site lies in the Crawford Upland of the unglaciated South Central Hill Region of Indiana. This area is underlain by alternate layers of sandstone, shale and limestone. Bottom land soils are poorly drained but moderately fertile. The climate is temperate, with an annual average temperature of 53.4° F., a maximum of 99° F., and a minimum of -18° F. Rainfall averages 44 inches annually, with an annual runoff of 18 inches.

The Patoka Reservoir site is within the exterior boundaries of the Hoosier National Forest, where forest wildlife management is handled by the Indiana Department of Conservation, Division of Fish and Game, under a cooperative agreement with the U.S. Forest Service.

Within a forty-mile radius of the proposed reservoir, there are two state parks, three state forests, one state beach area, and two state fish and game areas. One of the fish and game areas, Glendale, is still under development. When completed, it will cover 5,300 acres and include a 1,300-acre lake. Five of the other seven state areas have small impoundments totaling 349 acres. Limited recreational facilities are provided at all these state areas. Feasibility studies are being made for a several hundred-acre state recreational lake within twenty miles of the project area.

In the Patoka River Basin, several municipalities have constructed water supply reservoirs. These are Jasper, Ferdinand, Huntingburg, Oakland City, and Birdseye.

Of the nine major municipalities in the Patoka Basin, three have sewage disposal systems. Francisco and Huntingburg are on tributary streams and Jasper is on the main stem of the Patoka River. During low flow periods, the flow in the Patoka River below Jasper has been nearly 100 percent disposal plant effluent.

At the 1960 census, 74,650 people resided within 25 miles of the reservoir area and about 380,000 within a 50-mile radius.

Three state highways enter the reservoir area. State Route 145 runs north and south through the area. State Route 164 enters from the west and stops at State Route 145. State Route 64 runs east and west about six miles south of the main reservoir. Numerous county and township roads traverse the area.

Agriculture in the project area consists of intensive corn and grain farming in the flood plain. Most of the peripheral hills are grazed, unwisely cultivated, or have reverted to woody growth. Flood plain soils are fairly fertile, though difficult to drain because of texture. Hill soils are generally eroded and infertile from marginal farming operations. Purdue University owns and

operates the Southern Indiana Forage Experiment Farm of 1,060 acres just north of the damsite, where principles of grassland farming are practiced and demonstrated.

Industrial enterprises are few in the upper Patoka watershed. At Jasper, several industries are based on forest products and employ about 3,000 people. Some lumber is produced on the wooded hills. About 12 miles north of the reservoir site, a large resort area at French Lick is popular. Several fee fishing ponds in the vicinity of the project site are heavily patronized because of the lack of other fishing areas.

PLAN OF DEVELOPMENT

The damsite for Patoka Reservoir is at mile 118.3 on the Patoka River. About 168 square miles of the 860 square-mile watershed will be above the dam. The dam will be a rolled, earth embankment, 89 feet high and 2,500 feet long. An earth dike about 1,560 feet long and 35 feet high will be constructed across a low saddle in the left abutment about 3,000 feet southwest of the dam. The spillway will be an uncontrolled open channel through the right abutment. It will be 400 feet wide at elevation 550. The outlet works, in the toe of the right abutment, will consist of a cylindrical concrete conduit, nine feet in diameter; three control gates, 3.75 feet wide by 7.25 feet high; and a stilling basin. A multiple level outlet will allow for control of the quality of discharges for stream and tailwater fishery management. This reservoir will be operated for flood control, low-flow augmentation, fish and wildlife, and general recreation.

Pertinent engineering data are summarized in Table 1.

Table 1. Patoka Reservoir - Engineering Data

Item	Elevation (ft. m.s.l.)	Storage Cap. (Ac. Ft.)	Area (Acres)	Stream Miles Inundated
Stream Bed	467	--	--	--
Permanent Pool	506	13,200	2,010	5.1
Conservation Pool	536	167,500	8,880	29.5
Flood Control Pool	550	324,800	11,760	32.5

Data are not available on anticipated frequency or duration of flood flows. The Indiana Flood Control and Water Resources Commission desires that the reservoir be operated to meet low-flow objectives of 125 c.f.s. and 175 c.f.s. at Jasper and Princeton, respectively, for water-quality control and water

supply. The conservation pool (Table 1) has the capacity to meet these requirements. However, final determinations must await decisions as to possible local reimbursement for portions of these flows, as well as consideration of other requirements. For this reason, firm information on fluctuations of the conservation pool and related operational details is not available at this time.

Lands will be acquired for (1) the damsite, construction areas and permanent structures, (2) the reservoir area up to elevation 555, which allows a five-foot freeboard in elevation above the flood control pool to provide for adverse effects of saturation, wave action, and bank erosion, (3) a minimum of 300 feet horizontally from the flood control pool where the five-foot freeboard does not provide this area, and (4) selected sites along the shoreline and below the dam to meet present and future public requirements for outdoor recreation and fish and wildlife conservation. The total land acquisition for the project will be about 20,000 acres.

FISH AND WILDLIFE RESOURCES

Without-the-Project

Fishery

A total of 32.5 miles of the Patoka River lies within the project area above the damsite. At present this reach of the stream supports a low-quality, lightly-utilized, warm-water, stream fishery. Angling occurs primarily during the spring for suckers, catfish, and some smallmouth bass. Low stream flows during the summer and early fall and the lack of good pool-riffle development prevent the development of a higher quality stream fishery. Angler access to this reach of stream is very poor. During recent years, fishing pressure has amounted to approximately 2,600 angler trips per year. Because of their small size and intermittent nature, the tributary streams in the project area have been assigned no fishery value. The 35-mile section of the Patoka River between the damsite and the town of Jasper, Indiana, has fishery conditions similar to those in the project area.

At Jasper, the municipal sewage disposal plant, although considered adequate, contributes a substantial portion of the total stream-flow volume (during dry periods, the entire flow may be disposal plant effluent). In addition to this organic pollution, acid coal mine drainage from Gibson and Pike Counties enters the Patoka River near State Route 257 via the South Fork of the Patoka River and other lesser tributaries. This further impairs the fishery habitat of the stream. In general, the Patoka River downstream from Jasper can be considered marginal as fishery habitat and for angling. Angling occurs mostly in the spring and early summer, when stream flows provide enough dilution so that fish can move upstream from the Wabash River.

Wildlife

In the vicinity of the project, the Patoka River flood plain is about 75 percent cleared and intensively cultivated for grain crops. The remaining 25 percent consists of farm woodlots and wooded valley sides. Above the conservation pool (elevation 536), the land is approximately 50 percent cleared and 50 percent forested. This habitat supports both forest and farm game resources.

Forest game species include whitetail deer, gray squirrels and fox squirrels. Habitat conditions are excellent for deer and a moderate herd has developed in the Patoka Valley. However, poaching and depredations by dogs have interfered with its build-up. Squirrel populations are roughly evenly divided between gray squirrels and fox squirrels. They are very popular with local hunters.

Cottontail rabbit populations are good and support considerable hunting. The upper Patoka Valley is widely known for its excellent bobwhite quail populations and the fine quail hunting to be found there. Considerable numbers of hunters come from out of state and from other parts of Indiana to hunt quail in this area.

Since good farm-game habitat is closely associated with agricultural activities on fertile land, the upper Patoka Valley flood plain is particularly important to farm-game resources and hunting. Such good farm-game habitat is not plentiful in the unglaciated portion of Indiana. Conversely, forest-game habitat is very prominent around and near the project area, but relatively little such habitat is involved in the conservation pool. The loss of such a large area of farm-game habitat is a serious inroad on the already limited supply in the Patoka Basin, and every effort should be made to compensate for or lessen such losses.

Trapping of fur-bearing animals is light in the project area. However, raccoons are very abundant and they contribute significantly to the local hunting effort.

Waterfowl populations and hunting are largely limited to wood ducks produced locally along the main stem of the Patoka River. The 20,000-acre project area is currently supporting 4,165 upland hunter-days use and 15 waterfowl hunter-days use annually.

With-the-Project

Fish

The construction and operation of Patoka Reservoir will inundate 29.5 miles of the Patoka River, affect to some degree three miles of stream above the conservation pool, drastically change the first mile of stream below the dam, and alter the fishery habitat of the balance of the Patoka River to its mouth.

The 29.5 miles of stream habitat will be replaced by an 8,880-acre conservation pool characterized by some fluctuation of water levels, due to releases for downstream low flow regulation. Although firm decisions on low flow regulation have not been made, the level of releases being contemplated (125 c.f.s. at Jasper and 175 c.f.s. at Princeton) will not result in excessively great pool fluctuations. Development of a moderately productive reservoir fishery will not be impeded if provisions of the fishery plan are incorporated.

The three-mile reach above the conservation pool will suffer occasional inundation but will benefit from its proximity to the reservoir fishery. Overall utilization is expected to remain unchanged.

Assuming proper management and releases of not less than 75 c.f.s., a good potential for a productive tailwater fishery exists in the mile of stream below the dam.

The low flows presently being considered will improve stream conditions all the way to the Wabash River. Whether this improvement is sufficient to restore fishery productivity to these downstream reaches cannot be determined at this time. Therefore, no benefits have been assigned to this feature.

Wildlife

The conservation pool of Patoka Reservoir will inundate 8,880 acres of upland wildlife habitat. About 75 percent of this, or 6,660 acres, is particularly fine farm-game habitat producing good cottontail rabbit populations and hunting and exceptional quail populations and hunting. The Patoka River Valley is among the better quail producing areas in the state. The destruction of this fine habitat will be a very serious loss.

The remaining 2,220 acres is basically forest-game habitat, but also is important to the farm game.

Upland wildlife losses caused by the project will total 2,065 hunter days annually.

Other adverse effects on wildlife will occur on frequently flooded portions of the flood pool and on the narrow strip of land adjacent to the conservation pool which will be cleared of timber and other habitat.

About 4,000 acres will be developed for general recreational areas. Actual locations have not been determined, but hunting will not be permitted in certain of the high-use areas and some loss of hunter-day use will occur there.

According to present project formulation, approximately 22,600 acres will be acquired in fee. A total of 13,720 acres of project land will be above the conservation pool. Of this, 10,840 acres will be outside the flood pool and consist of the land in the 5-foot freeboard or 300-foot horizontal strip area, 2,600 acres of wildlife compensation land, 4,000 acres of general recreation

land, and severance lands. The 13,720 acres of land above the conservation pool is suited to extensive forest-game management.

The stream surface to be inundated by the conservation pool totals 73 acres, and 15 annual waterfowl hunter-days use will be lost.

Fish and Wildlife Plan

Fishery

The conservation pool would need 10 free public access sites, each consisting of access road, boat launching ramp down to elevation 520, and parking for 40 automobiles with boat trailers, to accommodate the estimated number of reservoir anglers. It is assumed that these access facilities would be provided as part of normal development for general recreational purposes. Incidental access should be provided by allowing existing roads to the conservation pool to remain open for public use.

The tailwater area would require a 25-car parking lot and appropriate access road for each bank of the stream to handle the anticipated numbers of tailwater anglers. About 20 acres of land in a strip 1,000 yards long by 50 yards wide on either side of the stream should be acquired in fee to make sufficient stream bank available for public angling. Public angling should be permitted in the entire tailwater up to the opening of the outlet works.

All major tributary arms of the conservation pool (Painter Creek, Lick Fork Creek, Fleming Creek, and Little Patoka River) and the main stem pool east of State Route 145 should be designated as fishing zones. The area near the tower and dam should be available to anglers.

The Corps of Engineers has made provision for a multiple-stage outlet. This structure should have portals with invert elevations of 501, 516 and 528 to permit the control of the quality of normal reservoir releases for the benefit of the tailwater and downstream fisheries. During the pre- and post-construction period, additional cooperative studies between this Bureau and the Indiana Department of Conservation, Division of Fish and Game, will be necessary to determine a pattern of releases geared to the actual situation that will prevail in the Patoka Reservoir.

Fishery management activities such as stocking, fish population control and pre- and post-impoundment surveys will be necessary to maintain productivity and maximum utilization. Fishery management responsibility should rest with the Indiana Department of Conservation, Division of Fish and Game.

All timber in the pool east of State Route 145 and in all tributary arms should be left uncut to provide desirable fish cover and angling conditions.

The Fishery Plan would require the purchase of about 20 acres of land below the dam adjacent to the tailwater. The value of land in the river bottoms is about $100 per acre. The initial cost of this 20 acres would be $2,000. Amortized over the 100-year project life at three percent interest, the average annual equivalent is $63. The acquisition and initial development of this 20 acres should be at Federal project cost.

The initial cost of development of the 8,880-acre reservoir fishery would amount to approximately $25,000, or $791 annually, amortized over the 100-year project life at three percent interest. These initial activities would consist of pre-impoundment surveys and fish stocking to establish a population complex designed to provide the maximum productive potential possible.

Annual fishery management operation and maintenance costs for the reservoir and tailwater would be approximately $5,000. This would cover remedial stocking, routine fishery surveys, limnological investigations, certain access-area upkeep, rough fish control, and law enforcement activities. Both the initial and annual fishery management cost would be borne by the Division of Fish and Game, Indiana Department of Conservation.

With the Fishery Plan in operation, Patoka Reservoir would support about 106,500 angler-days use annually valued at $106,500, while its tailwater fishery would sustain approximately 14,500 angler-days use annually valued at $21,750. The three miles of the Patoka River remaining in the project area would continue to support about 250 angler-days use annually valued at $250. Accounting for stream fishery losses of about 2,450 annual stream angler-days use, the total net increase in angling opportunity resulting from Patoka Reservoir would be approximately 119,000 angler-days use annually valued at $125,000.

Wildlife

Our draft report transmitted to you December 31, 1963 contained the recommendation that 1,500 acres of land be acquired below the reservoir to mitigate the loss of about 8,880 acres of farm and forest game habitat. Your letter of January 15, 1964 explains your reasons why you cannot concur in the acquisition of such lands. While we do not agree with the philosophy you have expressed, we have, in view of the urgency to expedite the movement of your report through channels, deleted that recommendation in this, our official report.

Instead, we are substituting a recommendation that about 2,600 acres of land be acquired above the dam to mitigate the loss of the 8,880 acres of game habitat. The recommended acreage consists of small, scattered parcels that would block in public ownership in the Hoosier National Forest. These parcels, along with present holdings of the U. S. Forest Service and lands to be acquired in fee, would result in a manageable unit of about 6,500 acres of woodland and farm game habitat. Wildlife management would be by the Conservation Department of the State of Indiana and the U.S. Forest Service under existing agreements.

Table 2. Effects of Patoka Reservoir on Fish and Wildlife Resources - Without and With the Project and Costs of Fish and Wildlife Plan (Assuming Full Implementation of the Plan)

	Without Project		With Project and Fish and Wildlife Plan					
	Area	Man Days of Use	Area	Man Days of Use	Increase in Use	Value of Increase	Amortized Initial Cost *	Annual Cost (O.&M.)
FISHERY								
Stream	32.5 mi.	2,600	3 mi.	250	--	--	--	--
Tailwater	1 mi.	80	1 mi.	14,500	14,420	$ 18,075	$ 63 1/	$ 100
Impoundment	--	--	8,880 ac.	106,500	106,500	$106,500	$ 791 2/	$5,000
WILDLIFE								
Upland Game	19,920 ac.	4,165						
Reservoir	8,880	2,065	8,880 ac.	0	0	0		
Other Project Lands	11,120	2,100	11,120 ac.	2,100	0	0		
Compensation Unit	0	0	2,600 ac.	1,300	--	--	$2,373 3/	
Waterfowl	73 ac. (Stream)	15	8,040 ac. (Size of pool Nov. 1)	1,688	1,673	$ 5,019	--	

* Initial costs amortized over 100-year project life at 3.0% interest (amortization factor - .03165).

1/ Amortized cost ($2,000) of 20 acres below dam for tailwater angler access.

2/ Amortized initial fishery management costs (Indiana Department of Conservation) $25,000.

3/ Amortized cost of 2,600 acres ($65,000) to compensate for wildlife losses plus amortized cost of initial development ($10,000).

By virtue of their small size and scattered location, it appears reasonable that the recommended areas can be acquired through severance or slight adjustments in the present land acquisition proposals. Such acquisition would do much toward insuring a truly multiple-purpose development of the Patoka Reservoir Project.

Waterfowl management would consist of providing nest boxes for wood ducks and leaving uncut all timber in the conservation pool east of State Route 145 and in all tributary arms.

All public roads which enter the project area should remain open to public use.

The Wildlife Plan would involve the purchase of 2,600 acres of additional land to be managed intensively for game to compensate for loss of upland game-hunting opportunity as a result of the 8,880-acre conservation pool. At $25 per acre the initial cost of this compensation unit would be $65,000. Amortized over the 100-year project life at three percent interest, the average annual equivalent is $2,057.

The cost of the 2,600 acres for compensation of losses should be a project cost. In addition, the project should bear the $10,000 cost of the initial minimum basic facilities for access, parking, service building and posting. Amortized over the 100-year project life at three percent interest, the average annual equivalent is $2,373 for total initial costs. All other operation and maintenance costs should be the responsibility of the Indiana Department of Conservation, Division of Fish and Game.

The Fish and Wildlife Plan would result in about 1,300 upland-game hunter-days use on the compensation unit, 2,100 upland-game hunter-days use on the project lands above the conservation pool, and 1,688 waterfowl hunter-days use on the pool, which on November 1 would be about 8,040 acres. Only in waterfowl hunting is there a net increase. It amounts to 1,673 waterfowl hunter-days use annually valued at $5,019. Table 2 summarizes utilization, benefits and costs of the Fish and Wildlife Plan.

RECOMMENDATIONS

In view of the existing and potential fish and wildlife resources in the project area and the potential of the reservoir under study to contribute to increased opportunity for the enjoyment of these resources, it is recommended that:

1. The conservation, improvement and development of fish and wildlife resources be among the purposes for which the project is authorized.

2. A total of 2,600 acres of additional land be acquired in fee at project cost, with initial development also at project cost. This area be licensed to the Indiana Department of Conservation under the terms of a Cooperative Agreement between that Department and the U. S. Forest Service. This upland-game hunting area is needed to compensate for project-occasioned wildlife losses.

3. About 20 acres of additional land adjacent to the tailwater be acquired and developed at project cost for angler access.

4. A multiple-level outlet facility be incorporated in the structure with three portals at elevations 501, 516, and 528.

5. A 25-car parking lot and appropriate access road be provided for each side of the tailwater channel. It is further recommended that public fishing be allowed in the tailwater up to the opening of the outlet conduit except during flood storage releases.

6. Ten reservoir angling and boating access sites be provided at the reservoir, each with access road or roads, parking for 40 cars with boat trailers, and a launching ramp extending into the conservation pool to elevation 520.

7. Public fishing be permitted from the reservoir side of the dam and in the area around the outlet tower.

8. Timber to be flooded by the conservation pool be left standing in selected areas.

9. Roads, scheduled to be abandoned, be left in the project area for use by hunters and fishermen.

10. Additional detailed studies of fish and wildlife resources be conducted, as necessary, after the project is authorized, in accordance with Section 2 of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.); and that such reasonable modifications be made in the authorized project facilities as may be agreed upon by the Director of the Bureau of Sport Fisheries and Wildlife and the Chief of Engineers for the conservation, improvement and development of these resources.

11. Federal lands and project waters in the project area be open to public use for hunting and fishing so long as title to the lands and structures remains in the Federal Government, except for sections reserved for safety, efficient operation, or protection of public property.

12. Leases of Federal land in the project area reserve the right of public use of such land for hunting and fishing.

13. All lands necessary for carrying out the various purposes of the project be acquired in accordance with the provisions of the Joint Policy of the Departments of the Interior and of the Army relative to reservoir project lands of February 16, 1962; and flowage easements be acquired only on those lands found not to have substantial value for recreation or fish and wildlife purposes.

14. A reservoir zoning plan be developed in connection with overall planning for the reservoir to insure that certain areas (or certain periods) will be available for fishing, hunting, and other wildlife purposes without conflicting uses for general recreation. It is further recommended that the reservoir zoning plan be developed cooperatively by the Corps of Engineers, the Bureau of Sport Fisheries and Wildlife, the Indiana Department of Conservation, and the U. S. Forest Service.

Please notify us of your proposed actions concerning these recommendations. Please advise us of any material changes in project plans.

The cooperation, information and assistance provided by your staff are appreciated.

Sincerely yours,

W. P. Schaefer

W. P. Schaefer
Acting Regional Director

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
830 West Broadway
Louisville, Kentucky 40201

ORLED-B 5 March 1964

Mr. R. W. Burwell
Regional Director
Fish and Wildlife Service
Bureau of Sport Fisheries and Wildlife
1006 West Lake Street
Minneapolis, Minnesota 55408

Dear Mr. Burwell:

This is to furnish you our comments and proposals relative to the recommendations contained in your report covering the Patoka Reservoir project. A copy of this letter will be included with your report in Appendix F of Interim Report No. 2, Wabash River Basin Comprehensive Study. Our comments on each of your recommendations are as follows:

Recommendation 1. Concur.

Recommendation 2.

a. Acquisition of 2600 acres of additional land for mitigation of project-caused damage to upland game hunting is not concurred in by this office and no provisions therefor are being made in our report. A factor in this decision is the cost that would be involved. In contrast to the estimated $65,000 land acquisition cost appearing in your report the estimate of this office, based on field inspection and analysis of comparable sales, is $360,000 for the area blocked out on the map (measuring 2700 acres) furnished by your office. A copy of our estimate is attached. Interest and amortization on this amount, plus the $10,000 initial development cost, would be $11,700 annually. Total hunter-days lost with the project, recognizing anticipated gain in water fowl hunting, would be 392 annually. Cost of mitigation would, accordingly, be $30 per hunter-day which is considered to be excessive.

b. With regard to our non-concurrence in recommendation 2, reference is made to our letter of 15 January 1964 which is referred to in the first paragraph under Wildlife, pg. 8 of your report. The following is quoted therefrom: "This recommendation introduces a concept of replacement-in-kind for each type of pre-project recreation as a relocation cost against the project. Recreation, including fishing and hunting, enters into the formulation and consequently shares in the cost of the project. The proposed replacement-in-kind would require that an additional cost be imposed on the recreation purpose for replacing a specific type of recreation activity that would be reduced or eliminated as a result of the over-all gain. Such costs would appear to constitute broad economic or social costs rather than financial costs in terms of project analysis."

"Accordingly, the over-all balance of gains in recreation achieved by the Patoka project, and relatively small net loss in hunting, are such that the District and Division Engineers cannot concur in the recommendation for acquisition of lands to compensate for project-occasioned loss."

c. With regard to indicated loss in upland game hunting, the premise is also advanced that significant mitigation would be afforded by the public availability and management of the project lands bordering the reservoir and the infrequently inundated reservoir lands, in contrast to such limited public use of private lands as may be permitted by the owners.

d. Concur in the objective of fish and wildlife management by Indiana Department of Conservation, for project lands determined available and licensed as leased for this purpose by the Corps of Engineers.

Recommendation 3. Concur. These lands would be acquired and used for general recreation, as well as for fishing recreation, if construction and other project needs do not automatically require their acquisition.

Recommendation 4. A multiple-level outlet facility would be included in design of project.

Recommendation 5. Concur in need for adequate parking and access to both sides. Tailwater area development would include facilities for picnicking, potable water, sanitation, etc., facilities for use as a general recreation area. Location and design of facilities will depend on detailed studies of needs, lands required for project construction, and operation and maintenance, public safety and other considerations.

Recommendation 6. Concur. It is expected that recreation areas and facilities provided, including future increments, would equal or exceed those recommended. Determination of number, location and extent of facilities at the public access sites will require detailed studies for appropriate development plans during design stages, as a part of studies of over-all recreational needs, including fishing and hunting.

Recommendation 7. This is a matter to be considered at time of development of detailed plans. However, considerations of public safety make it questionable whether fishing in these areas, particularly adjacent to the intake structures, can be allowed.

Recommendation 8. Concur, subject to consideration of all purposes and effects at the time of detailed planning.

ORLED-B 5 March 1964
Mr. R. W. Burwell

Recommendation 9. Concur in objective to make use of existing roads for access to the water, although it is not always practicable or desirable to leave all such roads available for public use. Good management practice in the over-all public interest generally is to provide for access at controlled locations, so that adequate policing, maintenance, sanitation, etc., can be provided. Reservoir management plans could consider operation of some reservoir area roads on a seasonal basis. Use of existing roads would be given detailed consideration in Master Plan studies, including fish and wildlife area development and management plans.

Recommendation 10. Concur.

Recommendation 11. Concur, subject to additional proviso at end, as follows: "or as may be determined necessary for other project purposes in consideration of over-all public interest."

Recommendation 12. Would favorably consider to extent practicable. Feasibility would depend upon lease purposes, location and other variable factors and would require that determination be made on an individual lease basis.

Recommendation 13. Present report plans and estimates are based on fee acquisition of the entire reservoir area, to the limits established by the Joint Policy. In the acquisition process, consideration of taking to reduced limits or lesser estate on any individual tracts would be a matter for detailed real estate studies pursuant to the exception provisions of the Joint Policy.

Recommendation 14. Concur in general objective. Procedures employed in detailed studies, planning and formulation of the Master Plan for development and management of the project area will give full consideration, along with other public needs and purposes, to fish and wildlife conservation, enhancement and recreation.

Your cooperation and that of your staff in connection with preparation of the subject report is sincerely appreciated.

Very truly yours,

1 Incl
Real Estate Estimate

W. ROPER
Colonel, Corps of Engineers
District Engineer

ORLRE

PATOKA RESERVOIR

Gross Appraisal

a. Fee Title

1. Land:					
Homesites	27	@ $	400	$10,800	
Cropland	140 Ac.	@	110	15,400	
Pasture	920 "	@	35	32,200	
Woodland	1,640 "	@	15	24,600	
					$ 83,000.00
2. Improvements:					
Sets of Buildings	20	@ $	3,900	$78,000	
Dwellings	5	@	2,300	11,500	
Churches (2)				6,000	
					95,500.00
3. Isolation:					
4 Tracts including land and improvements					22,500.00
b. Valuation of Mineral Rights					-0-
c. Severance Damage					17,850.00
d. Contingencies					32,828.00
e. Resettlement Cost					
28 Family Units		@ $	500		14,000.00
f. Relocation Costs					
Patoka Church Cemetery, 200 Graves		@ $	200	$40,000	
McDonald Chapel Cemetery, 95 Graves		@	200	19,000	
					59,000.00
g. Acquisition Cost					
38 Tracts		@ $	900		34,200.00
					$358,878.00
				SAY:	$360,000.00

RECONNAISSANCE REPORT

ON THE

RECREATION RESOURCES

OF THE

LINCOLN RESERVOIR

WABASH RIVER BASIN

ILLINOIS

PREPARED FOR:

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE

CORPS OF ENGINEERS

LOUISVILLE, KENTUCKY

BY

U. S. DEPARTMENT OF THE INTERIOR

BUREAU OF OUTDOOR RECREATION

LAKE CENTRAL REGION

OHIO RIVER BASIN OFFICE

LEBANON, OHIO

JANUARY 1964

EXHIBIT F-4

APPRAISAL OF MULTI-PURPOSE PROJECT FOR RECREATION

Preface: The following appraisal is made on the assumption that the plan of operation will not adversely affect the recreation use of the project. It applies to this particular site only and does not constitute a unit evaluation of a proposed system of reservoirs in that possible effects of other sites upon this site have not been considered.

1. PROJECT NAME:

Lincoln Reservoir

2. LOCATION:

The Lincoln Reservoir is to be located on the Embarrass River, 103.1 miles upstream from its confluence with the Wabash River. The reservoir site is situated in Coles, Cumberland and Douglas Counties, Illinois; and is located 47 miles southeast of Decatur, Illinois, and 38 miles west of Terre Haute, Indiana. The City of Charleston, Coles County, is adjacent to the north shore of the reservoir.

3. GENERAL CHARACTERISTICS OF PROJECT AREA PERTINENT TO RECREATION USE AND DEVELOPMENT

The physical character of the local terrain resulted from glacial action which formed a terminal morain in the project area. This morain and turbulent stream action caused formation of what is known as the Embarrass Breaks, a rugged-type terrain encompassing both shorelines of the Embarrass River flood plain. These rugged slopes are covered with second growth hardwood forests. They will add scenic splendor to the reservoir, but their precipitous nature will prove a limiting factor in their suitability for recreation development.

Land use of the plateau-like upland areas is comprised of largely marginal row-crop and pasture farms and scattered woodlots. Corn and

soybeans are the predominant crop cover with some activity in wheat. Hog and beef cattle raising are secondary pursuits.

Numerous gravel roads intersect the high ridges adjacent to the site. State Highway 130 crosses the reservoir site southeast of Charleston and then proceeds south parallel to the east shore of the proposed reservoir at a distance of approximately one mile. This highway will intersect Interstate Highway 70 at Greenup, about 10 miles south of the project site. The west shore is served by a bituminous surfaced road which is presently part of the Lincoln Heritage Trail route.

4. FEATURES OF THE RESERVOIR AND EFFECTS ON RECREATION

The source of project engineering and operation data is the Louisville District, Corps of Engineers. Project purposes to be served by the reservoir will include flood control, general recreation, fish and wildlife recreation, water supply, and water quality control. The dam will rise to elevation 648 feet 1/, will be a maximum of 100 feet high and about 2,400 feet long, and will control the runoff from a drainage area of 915 square miles.

The reservoir will have three storage pools - minimum, seasonal, and flood control. The minimum pool will be the lowest level to which the water will be drawn. The seasonal pool will be filled each year, as runoff conditions permit, from about early May to early September. At this time the seasonal pool will be gradually withdrawn, providing an increase to the normally low natural flows and making possible additional flood control storage. Information is not available as to the probable minimum instantaneous flow to be provided by the project

nor the probable frequency of drawdown to the minimum pool level in winter. Tentative data concerning the reservoir appear below.

Pool	Elevation (ft.msl)	Capacity (acre-feet)	Area (acres)	Length (main stream) (miles)
Flood Control	629	538,300	21,250	58
Seasonal	596	126,765	6,760	34
Minimum	584	61,315	4,310	26

1/ All elevations are in feet and refer to mean sea level datum.

The reservoir will have a scenic forested shoreline with a few long embayments to add to the recreation value of the site. The major portion of the reservoir, at both minimum and seasonal pool levels, will be situated southeast and south of Charleston. Thus, extensive public recreation facilities logically should be located along the downstream flanks of the reservoir. Additionally, a few public boat marinas, including one below the dam, should be developed at strategic locations. Development of these latter sites will facilitate maximum public utilization of the reservoir's recreation potential.

5. REGION SERVED AND POPULATION.

There is a lack of natural lakes or large impoundments within the general region. Thus, for purposes of estimating utilization of the proposed reservoir, the zone of influence is estimated to include the population within a 50-mile radius of the site. Included with this zone are three Standard Metropolitan Statistical Areas: Decatur, Illinois (population 118,257); Champaign-Urbana, Illinois (132,436); and Terre Haute, Indiana (108,458). Danville, Illinois, within a population of 41,856, lies adjacent to the zone.

A population of approximately 600,000 (1960 Census) resides within the 50-mile zone of influence. A large portion of this area is rurally occupied. The population can be expected to increase to 753,000 people by 1975 and to 1,087,500 by the year 2000.

6. RELATED RECREATION AREAS

Within Coles County and adjacent to the reservoir there are two state parks; (1) Lincoln Log Cabin State Park (86 acres) and (2) Fox Ridge State Park (845 acres). Moore Home State Memorial is within 2 miles of the dam site. Lake Charleston, a 404-acre water supply reservoir at which recreation facilities are operated by the Charleston Park Department, is the only significant urban, water-oriented, recreation facility available in the area. This reservoir, which would be inundated by four feet at minimum pool elevation 584, supports without-the-project general recreation utilization estimated at 30,000 visitor days.

The following non-urban recreation areas are located within 50 miles of the reservoir site:

Area	County	Visitor Days (1961)
Red Hills St. Pk.	Lawrence	85,452
Lincoln Trail St. Pk.	Clark	94,202
Kickapoo St. Pk.	Vermilion	81,433
Fox Ridge St. Pk.	Coles	57,752
Lincoln Log Cabin St. Pk.	Coles	65,885
Spitler Woods St. Pk.	Macon	30,034
Shelby Co. St. Forest	Shelby	UNKNOWN
Bryant Cottage St. Memorial	Piatt	UNKNOWN
Moore Home St. Memorial	Coles	UNKNOWN
		414,758

7. TYPES OF RECREATION FOR WHICH THE PROJECT IS SUITED

The large impoundment and attendant scenic terrain will be suitable for water-related activities and a variety of other recreation uses. Sightseeing, picnicking, swimming 2/, boating and camping will be major activities.

The two State Park areas adjacent to the proposed reservoir also could contribute in forming a nuculeus for recreation development within the area. Current facilities will need to be expanded and additional facilities developed to meet the recreation demands expected by construction of the reservoir.

8. RECOMMENDED PLAN OF IMPROVEMENT

Lincoln Reservoir will have the inherent capacity to substantially fulfill public, water-oriented, recreation needs in the zone of influence. However, as a prerequisite to fulfilling these needs it will be necessary to acquire and develop about 5,000 acres of lands adjacent to the reservoir, essentially as shown on the attached map. Since most of the lands immediately adjacent to the reservoir are steep and not suitable for development, it will be necessary that a substantial portions of lands to be developed for recreation be acquired some distance from the reservoir. The Illinois Department of Conservation has indicated interest in developing and administering the recreational use of these lands. Additionally, in order to assure optimum utilization of the reservoir recreation potential, a few minimum public access sites will need to be developed. The plan of improvement outlined below includes initial and deferred plans of development.

2/ It is assumed that domestic waste effluent emanating from Charleston and Mattoon will not restrict the usefulness of the reservoir.

A. Initial Plan

(1) Purpose

The protection and development of the recreation potential of the project site and the meeting of immediate needs for recreation in the area of influence would be the prime goals of facilities to be developed in the initial plan 3/. This plan should be developed to accommodate a design load of 8,100 and an estimated annual attendance of 425,000 visitor days. The plan should be confined primarily to day-use recreation activities with only limited overnight camping.

(2) General Description

The Fox Ridge State Park and the Lincoln Log Cabin State Park would form a land nucleus from which to make major development of day-use activities. These sites would need to be expanded so as to provide recreation lands adjacent to water. Limited day-use areas could be developed in conjunction with boat launching sites on Kickapoo Creek, on the Embarrass River due east of Charleston, on the Embarrass River where the Little Embarrass River joins, and at the tailwater area, substantially as shown on the attached map.

B. Deferred Plan

(1) Purpose

The deferred plan of improvement would be instigated five years after project completion and would be designed to provide facilities for optimum use of the recreation potential of the site. The recreation activities provided for under this plan would include swimming, picnicking, boating, hiking, nature trails, camping, trailer camps, and organized group camping. When completely developed the

3/ First five years following project construction.

recreation facilities would accommodate an estimated additional design load of 12,900 and an additional annual visitation of 675,000. Thus the project recreation lands would be developed to provide for a maximum design load of 21,000 and an estimated optimum utilization of 1,100,000 visitor days of general recreation.

(2) General Description

The recreation potential of the topography surrounding the proposed reservoir poses problems and is such that the designation of a specific site for recreation development will require a more detailed study of the reservoir area. The following plan of development refers to general areas suitable for recreation.

Development on the west shore should expand the existing State Park facilities and extend up to about half way between Indian Creek and Kickapoo Creek. Benches, marinas, camping, sightseeing, and hiking-trail facilities for optimum recreation activity could be suitably developed in this area. The Fox Ridge State Park area could be similarly expanded and developed on the east shore.

9. BENEFITS

Monetary evaluations of general recreation are in general accordance with the October 31, 1963 draft of "Evaluation Standards for Primary Outdoor Recreation Benefits," as prepared by the Joint Task Force on Recreation of the Recreation Advisory Council and the Ad Hoc Water Resources Council. This procedure is used to evaluate benefits which accrue to general recreation as a result of construction of a water-development project.

The estimates of utilization include only the visitation expected to occur at public developments and access sites created at the project, less those amounts already being provided by existing public facilities which are expected to be degraded or rendered useless by construction of the project. In this case, the project reservoir will inundate Lake Charleston causing losses of recreation opportunities.

In the following table the estimate of optimum visitation (50 year) to the project indicates the maximum number of visitor-days expected to occur at the proposed public recreation facilities. The average annual, net, monetary, benefits are provided for use in approximating the benefit/cost ratio.

ESTIMATES OF OPTIMUM AND AVERAGE ANNUAL

VISITATION AND VALUES OF PUBLIC RECREATION AT LINCOLN RESERVOIR

WITHOUT AND WITH THE PROJECT

	Without the Project Lake Charleston			With the Project Lincoln Reservoir			
Year	Rec. Days	Unit Value	Rec. Value	Rec. Days	Unit Value	Rec. Value	Net 4/ Benefit
5	30,000	$.50	$15,000	425,000	$.75	$318,750	$304,000
50	30,000	$.50	$15,000	1,100,000	$1.25	$1,375,000	$1,360,000
Avg. Ann. 50-year	30,000	$.50	$15,000	708,950	$1.20	$850,740	$836,000
Avg. Ann. 100-year	30,000	$.50	$15,000	904,475	$1.23	$1,112,504	$1,108,000

4/ Rounded to nearest thousand.

10. RECREATION DEVELOPMENT COSTS

The estimated recreation development costs for initial and deferred recreation development are shown in the following table. These amounts do not include the cost of land acquisition. These are preliminary estimates, and refinements, including land costs, will be necessary as occasion demands.

RECREATION DEVELOPMENT COSTS

	Initial	Deferred	Total
Facilities	$1,553,000	$1,740,000	$3,293,000
Planning, Overhead and Contingencies	388,000	435,000	823,000
TOTAL	$1,941,000	$2,175,000	$4,116,000

The total annual equivalent of construction costs for recreation facilities is based on a 25-year period at 3.0%. This figure is currently used for what is considered as the life of recreation facilities for the project and is shown as follows:

TOTAL ANNUAL EQUIVALENT OF CONSTRUCTION COSTS FOR RECREATION FACILITIES

	Initial	Deferred	Total
Operation and Maintenance	$ 85,000	$135,000	$220,000
Ann. Equiv. of Constr. Costs	111,000	125,000	236,000
TOTAL	$196,000	$260,000	$456,000

11. RECOMMENDATIONS

A. General recreation should be included as one of the purposes for which the project is authorized.

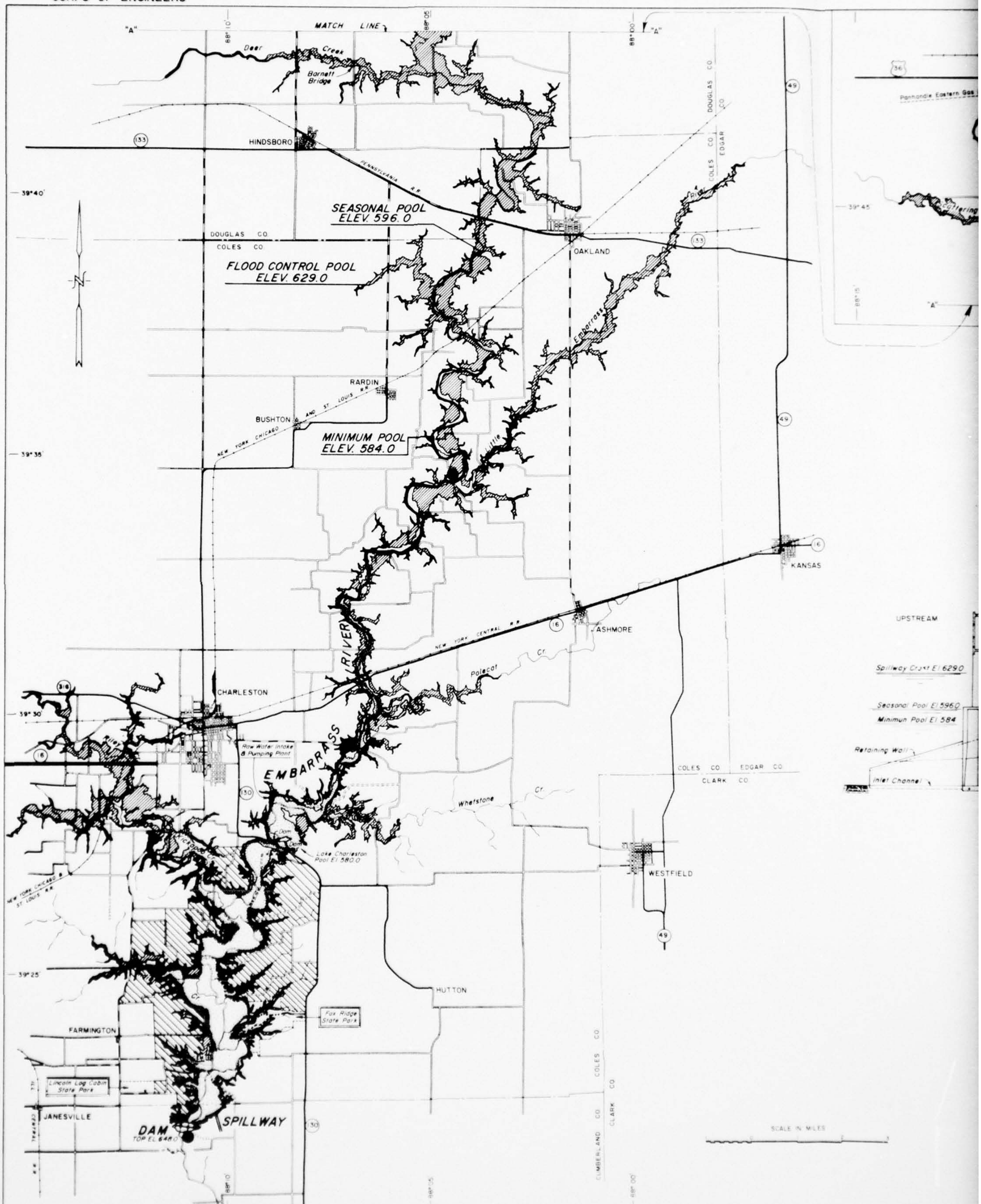
B. Approximately 5,000 acres of land, located substantially as shown on the attached map, should be acquired in fee simple at project cost for general recreation. The responsibility for the development and administration of the recreation use of these lands should be vested in the Illinois Department of Conservation.

C. All minimum-facility public access sites shown on the attached map should be provided at project-cost.

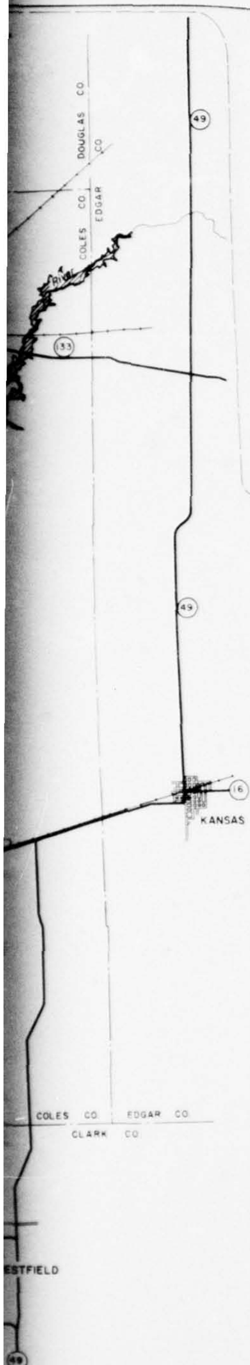
D. Consideration should be given to the development of a zoning plan for project lands and waters to insure that optimum opportunities for general recreation may be realized without conflicting with fishing, hunting, and associated wildlife purposes; such zoning plan to be developed cooperatively by the Corps of Engineers, the Bureau of Outdoor Recreation, the Bureau of Sport Fisheries and Wildlife, and the Illinois Department of Conservation.

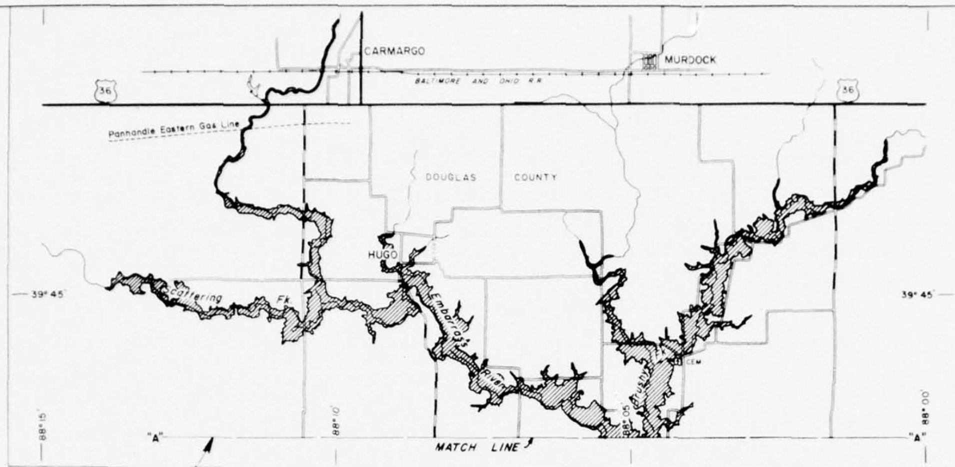
E. The report of the District Engineer should recognize the need for additional recreation studies and should provide for such reasonable modifications, including the extent and location of recreation lands, as may be agreed upon by the Corps of Engineers and the Bureau of Outdoor Recreation.

CORPS OF ENGINEERS



U. S. ARMY





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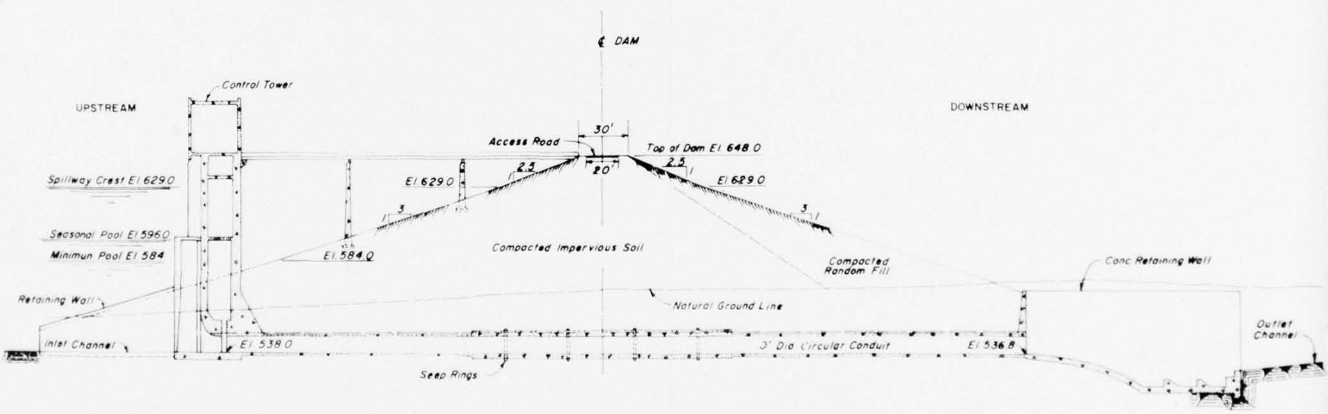
VICINITY MAP

SCALE IN MILES

25 0 50 100



SECTION - OUTLET WORKS AND EMBANKMENT

NOTE
Data are tentative and subject to revision

LEGEND

FLOOD CONTROL POOL ELEV. 629.0

SEASONAL POOL ELEV. 596.0

MINIMUM POOL ELEV. 584.0

SCALE IN MILES

PREPARED BY THE BUREAU OF OUTDOOR RECREATION. LEBANON, OHIO
OHIO RIVER BASIN OFFICE DEC. 1963

Lands proposed for Public Recreation

Minimum Public Access Sites

PLAN CONSIDERED
FOR
LINCOLN RESERVOIR
EMBARRASS RIVER, ILLINOIS

LOUISVILLE DISTRICT DECEMBER 1963

2

COPY

STATE OF ILLINOIS
DEPARTMENT OF CONSERVATION
Springfield

William T. Lodge
Director

March 3, 1964

Mr. Roman H. Koenings
Regional Director
U. S. Department of Interior
Bureau of Outdoor Recreation
Lake Central Region
15 Research Drive
Ann Arbor, Michigan, 48103

Dear Mr. Koenings:

We have your letter of February 27, 1964, and the Reconnaissance Report on the Recreation Resources of the Lincoln Reservoir, Wabash River Basin, Illinois, prepared for the U. S. Army Engineer District, Louisville Corps of Engineers, Louisville, Kentucky, by the U. S. Department of the Interior, Bureau of Outdoor Recreation, Lake Central Region, Ohio River Basin Office, Lebanon, Ohio.

On December 10, 1963, Mr. Arnold Kugler of our engineering division together with Mr. Rudy Stinauer, area fish biologist and Mr. Robert Franz of your Lebanon, Ohio office made a field reconnaissance of the reservoir area. The general comments at the time of the field survey followed the line of your recommendations to the U. S. Corps of Engineers. After reviewing your report, we wish to concur in the recommendations as they have been prepared by your office. This can be a very valuable and much needed recreation improvement for the East Central Illinois Region.

Very truly yours,

Sgd/William T. Lodge

WILLIAM T. LODGE
Director

WTL:Pl

Exhibit F-4

RECONNAISSANCE REPORT

ON THE

RECREATION RESOURCES

OF THE

CLIFTY CREEK RESERVOIR

WABASH RIVER BASIN

INDIANA

PREPARED FOR:

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE

CORPS OF ENGINEERS

LOUISVILLE, KENTUCKY

BY

U. S. DEPARTMENT OF THE INTERIOR

BUREAU OF OUTDOOR RECREATION

LAKE CENTRAL REGION

OHIO RIVER BASIN OFFICE

LEBANON, OHIO

JANUARY 1964

EXHIBIT F-4

APPRAISAL OF MULTI-PURPOSE PROJECT FOR RECREATION

Preface: The following appraisal is made on the assumption that the plan of operation will not adversely affect the recreation use of the project. It applies to this particular site only and does not constitute a unit evaluation of a proposed system of reservoirs in that possible effects of other sites upon this site have not been considered.

1. PROJECT NAME:

Clifty Creek Reservoir

2. LOCATION:

The project site is located at river mile 18.4 on Clifty Creek in Bartholomew and Decatur Counties, Indiana, 13 miles east of Columbus and 14 miles west of Greenburg. The village of Hartsville lies adjacent to the east shoreline of the proposed reservoir.

3. GENERAL CHARACTERISTICS OF PROJECT AREA PERTINENT TO RECREATION USE AND DEVELOPMENT:

The land surface area of the proposed reservoir area is that of slightly rolling hills sloping into narrow stream bottom lands.

The terrain adjacent to the proposed reservoir site is flat, open farmland. Corn, hay, clover, tobacco and sorghum are the principal crops with dairying and hog raising as secondary endeavors. Land use is intensive and many properous-appearing farms are located within the upland areas.

The Clifty Creek segment of the project area is a shallow and narrow river valley. Most forest cover in the area is within this bottomland zone. Stream valley forest cover is composed primarily of sycamore, black oak, hackberry and redbud.

The Falls Fork arm of the project area contains a falls with a 10-15 foot high cliff face at alevation 700 feet.1/ A small turnout along country-route 330 W provides access to the falls. This stream becomes completely dry at times. The stream beds and some of the forested slopes along Clifty Creek and Falls Fork show outcrops of limestone. Access to the area is over State Route 46. This road will have to be relocated in the construction of the reservoir. Many gravel roads traverse the main section of the reservoir and will provide sufficient access to recreation lands.

4. FEATURES OF THE RESERVOIR AND EFFECTS ON RECREATION:

The source of project engineering and operation data is the Louisville District, Corps of Engineers. Project purposes to be served by the reservoir will include flood control, general recreation, and fish and wildlife recreation. The dam will rise to elevation 750, will be a maximum of 85 feet high and 6,580 feet long, and will control the runoff from a drainage area of 140 square miles.

The reservoir will have three storage pools - minimum, seasonal, and flood control. The minimum pool will be the lowest level to which the reservoir will be drawn. The seasonal pool will be filled each year, as runoff conditions permit, from about early May to early September. At this time the seasonal pool will be gradually withdrawn, augmenting the normally low natural flows and making possible additional flood control storage. This office does not have data available as to the probable minimum instantaneous flow to be provided by the project, nor information as to the probable frequency of drawdown to the minimum pool level in winter.

1/ All elevations are in feet and refer to mean sea level datum.

Tentative data concerning the reservoir appear below.

Pool	Elevation (ft. msl)	Capacity (acre-feet)	Area (acres)	Length of Pool (main stream miles)
Flood Control	745	56,208	2,390	8
Seasonal	720	18,515	919	6
Minimum	705	7,655	548	5

The seasonal pool at elevation 720 will establish a shoreline having two arms and numerous small inlets. The reservoir will extend in two distinct arms away from the dam, the Clifty Creek arm extending north and the Falls Fork arm extending south. The village of Hartsville, because of its location adjacent to the east shore of the north arm of the reservoir, will be protected from the reservoir by a levee. The maximum variance in land elevations within a mile of the reservoir is 40 feet. The area adjacent to the project is relatively flat and much of the shoreline within the recreation sites will be suitable for beach development and boat launching facilities.

5. REGION SERVED AND POPULATION

The local zone of influence would extend 25 miles and contain portions of 10 counties. The population within this zone is 202,000 according to 1960 census figures. This population is expected to increase to 307,000 by 1975 and 497,000 by the year 2000.

Adjacent to this zone is the Standard Metropolitan Statistical Area of Indianapolis (1960 population - 697,567). This area is expected to provide the major portion of visitation from outside the local zone.

Interstate Highway 65 will pass 16 miles west of the reservoir site while Interstate Highway 74 will cross 14 miles northwest of the site. These highways will provide mobility from Indianapols, Indiana, Cincinnati, Ohio, and Louisville, Kentucky; therefore, they are considered to contribute to the potential visitation to the project.

6. RELATED RECREATION AREAS

Within 25 miles of the reservoir site there are 613 acres of non-urban recreation lands. These are located in Muscatatuck State Park and Selmier State Forest, Jennings County. There are not any attendance statistics available for these areas.

7. TYPES OF RECREATION FOR WHICH PROJECT IS SUITED

Due to the limited size of the impoundment, day-use type activities will comprise the major recreation use of the site. Picnicking, swimming, and boating will be the principal day-use activities.

Tent camping, group camping and allied activities will be suitable at areas more removed from the reservoir. Location of these facilities will be partially dependent on the relocation of that section of State Route 46 scheduled to be inundated by impoundment of water.

8. RECOMMENDED PLAN OF IMPROVEMENT

Clifty Creek Reservoir project will have the inherent capacity to substantially fulfill public-water-oriented recreation needs in the local zone of influence. However, as a prerequisite to fulfilling these needs it will be necessary to acquire and develop about 600 acres of land adjacent to the reservoir, essentially as shown on the

attached map. The Indiana Department of Parks has indicated interest in developing and administering the recreational use of these lands. In order to assure optimum utilization of the reservoir recreation potential, it will be necessary to develop one or two additional minimum public access sites. The plan of improvement outlined below includes initial and deferred plans of development.

A. Initial Plan

(1) Purpose

The primary purposes of the initial plan 2/ are the protection of the recreation potential and natural resources of the project site and development to meet the immediate needs for recreation in the zone of influence. This plan should be developed for a design load of 3,800 and an estimated annual visitation of 200,000. Initial recreation development would be confined primarily to day-use recreation activities with limited overnight camping.

(2) General Description

Three areas having a potential for development are shown on the enclosed map.

The land situated generally between Hartsville on the north and Falls Fork on the south has resources and opportunities for recreation development. Major portions of the day-use facilities required under the initial plan should be provided in this area. Numerous bays, inlets, should be developed in conjunction with boating and swimming, the peninsulas developed for picnicking.

2/ First five years following project construction.

AD-A036 533 ARMY ENGINEER DISTRICT LOUISVILLE KY F/G 8/6
WABASH RIVER BASIN COMPREHENSIVE STUDY COVERING RESERVOIR SITES--ETC(U)
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The two areas situated on the west shore of the proposed reservoir should be developed to provide overnight camping facilities as well as limited beach and boat launching facilities in the initial plan.

Access points, with some basic facilities, should be planned and provided for in the upper reaches of the seasonal pool and at the tailwater area.

In this stage, a tree planting program should be started to complement planned ultimate development for the site.

B. Deferred Plan

(1) Purpose

The deferred plan of improvement would be designed to provide facilities for optimum use of the recreation potential of the site. The recreation activities provided for under this plan would include swimming, picnicking, boating, camping, nature trails, and organized group camping. When completely developed the recreation facilities would accommodate an estimated additional design load of 11,400 and an additional annual visitation of 600,000 persons. Thus, the project recreation lands would be developed to provide for a total design load of 15,200 visitors and an estimated optimum utilization of 800,000 visitor-days.

(2) General Description

The recreation potential of the topography surrounding the proposed reservoir is such that designation of specific boundaries for recreation development sites would require a more detailed study

of the reservoir area. However, the Indiana Department of Conservation, Division of Conservation, Division of State Parks, has considered the plan and concurs with the general location and amount of lands necessary for recreation development at the site.

Development in this deferred stage would be the expansion of facilities constructed in the initial stage of development. Although development in this stage should continue to emphasize day-use activities development of tent camping facilities and trails should take place consistant with providing optimum recreation use on the relatively limited acreage.

9. BENEFITS

Monetary evaluations of general recreation are based on the October 31, 1963 draft of "Evaluation Standards for Primary Outdoor Recreation Benefits," as prepared by the Joint Task Force on Recreation of the Recreation Advisory Council and the Ad Hoc Water Resources Council. This procedure is used to evaluate benefits which accrue to general recreation as a result of construction of the proposed project.

The estimates of utilization include only the visitation expected to occur at public developments and access sites created at the project. In the following table the estimate of optimum visitation (50th year) to the project indicates the maximum number of visitor-days expected to occur at public recreation facilities. The average annual net monetary benefits are provided for use in determining the benefit/cost ratio.

ESTIMATES OF MAXIMUM AND AVERAGE ANNUAL VISITATION AND

VALUES OF PUBLIC RECREATION AT CLIFTY CREEK RESERVOIR

Year	Recreation Days	Benefit Value	Recreation 3/ Benefits
5	200,000	$0.75	$150,000
50	800,000	$1.10	$880,000
Avg. Ann. 50-year	460,000	$1.07	$492,000
Avg. Ann. 100-year	630,000	$1.08	$680,000

3/ Rounded to the nearest thousand.

10. RECREATION DEVELOPMENT COSTS

The estimated costs for initial and deferred recreation development are shown in the following table. This amount does not include the cost of land acquisition nor interest during construction.

RECREATION DEVELOPMENT COSTS

	Initial	Deferred	Total
Facilities	$ 957,000	$1,539,000	$2,496,000
Planning, Overhead, and Contingencies	239,000	385,000	624,000
TOTAL	$1,196,000	$1,924,000	$3,120,000

The total annual equivalent of construction costs for recreation facilities is based on a 25-year period at 2-7/8%. This figure is currently used for what is considered as the life of recreation facilities for the project.

ESTIMATED ANNAUL CHARGES FOR RECREATION FACILITIES COSTS

	Initial	Deferred	Total
Operation & Maintenance	$ 40,000	$120,000	$160,000
Annual Equivalent of Construction Costs	68,000	109.000	177,000
TOTAL	$108,000	$229,000	$377,000

11. RECOMMENDATIONS

A. General recreation should be included as one of the purposes for which the project is authorized.

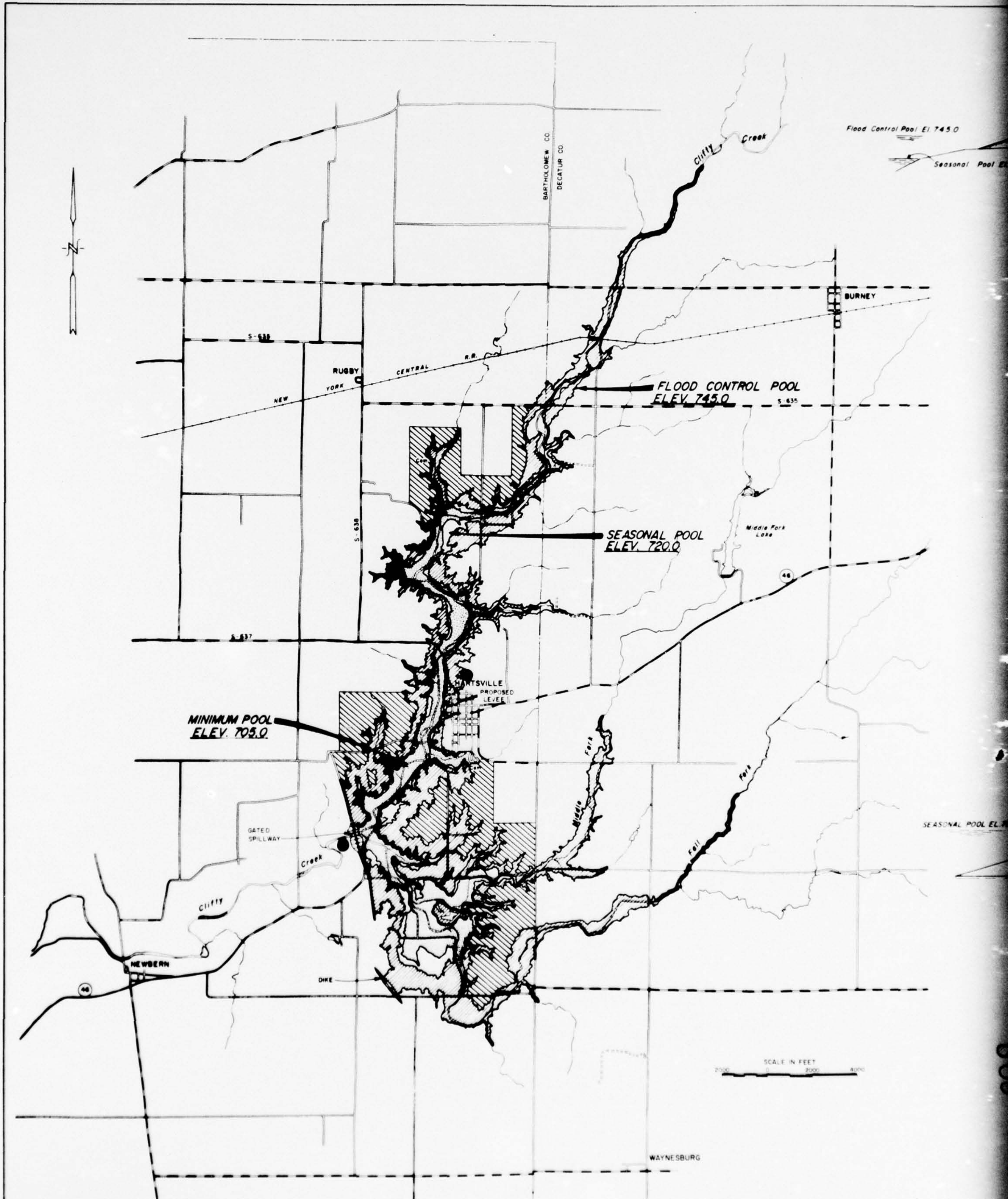
B. Approximately 600 acres of land, located substantially as shown on the attached map, should be acquired in fee simple at project cost for general recreation. The responsibility for the development and administration of the recreation use of these lands should be vested in the Indiana Department of Conservation.

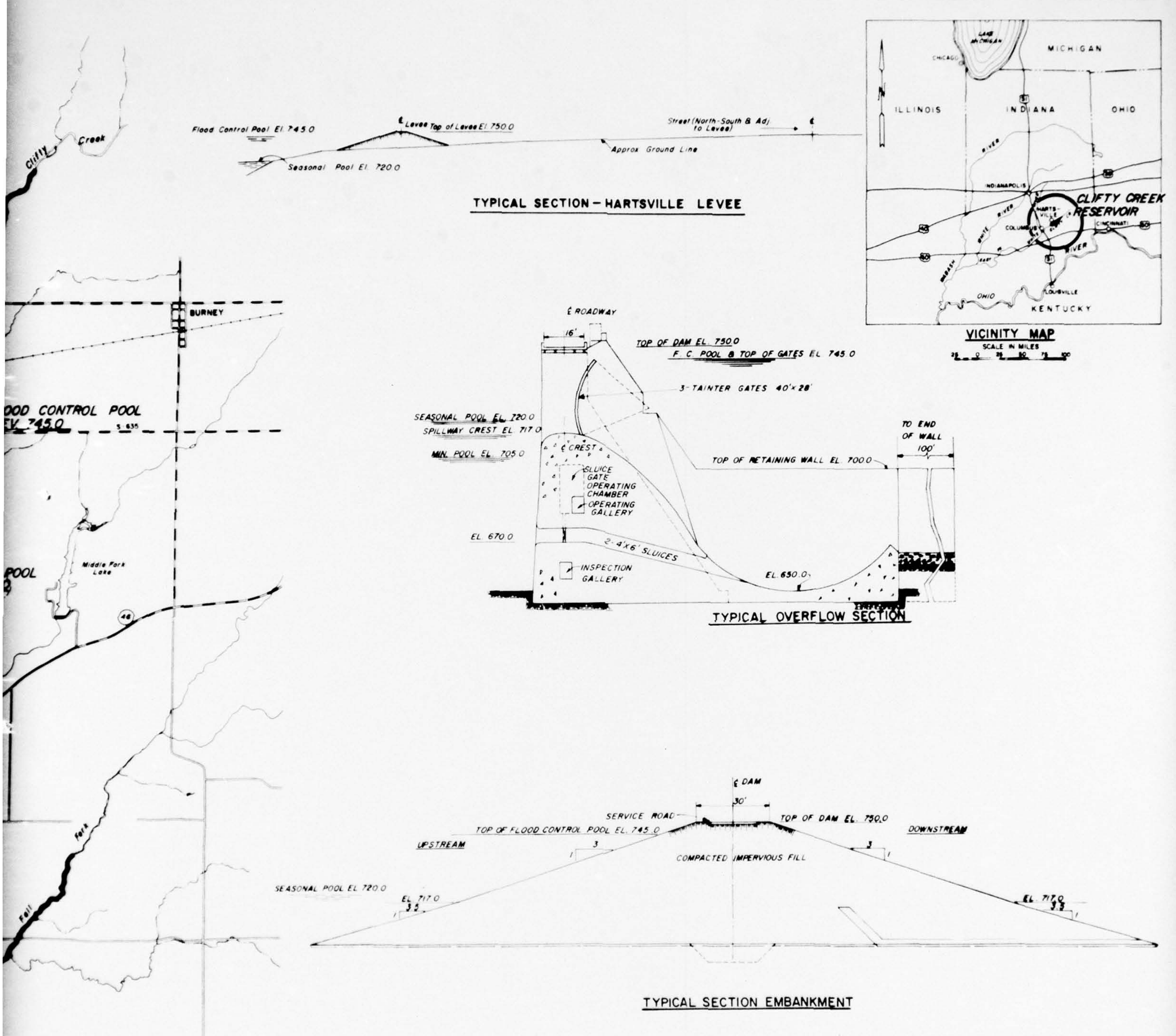
C. All minimum-facility public access sites shown on the attached map should be provided at project cost.

D. Consideration should be given to the development of a zoning plan for project lands and waters to insure that optimum opportunities for general recreation may be realized without conflicting with fishing, hunting, and associated wildlife purposes; such zoning plan to be developed cooperatively by the Corps of Engineers, the Bureau of Outdoor Recreation, the Bureau of Sport Fisheries and Wildlife, and the Indiana Department of Conservation.

E. The report of the District Engineer should recognize the need for additional recreation studies and should provide for such reasonable modifications, including the extent and location of recreation lands, as may be agreed upon by the Corps of Engineers and the Bureau of Outdoor Recreation.

CORPS OF ENGINEERS





NOTE
DATA ARE TENTATIVE AND SUBJECT TO REVISION

LEGEND

FLOOD CONTROL POOL ELEV. 745.0
SEASONAL POOL ELEV. 720.0
MINIMUM POOL ELEV. 705.0

SCALE IN FEET
2000 0 2000 4000

PREPARED BY THE BUREAU OF OUTDOOR RECREATION. LEBANON, OHIO
OHIO RIVER BASIN OFFICE DEC. 1963

Lands Proposed for Public Recreation.
Minimum Public Access Sites.

PLAN CONSIDERED FOR CLIFTY CREEK RESERVOIR
CLIFTY CREEK, INDIANA

LOUISVILLE DISTRICT DECEMBER 1963

RECONNAISSANCE REPORT

ON THE

RECREATION RESOURCES

OF THE

PATOKA RESERVOIR

WABASH RIVER BASIN

INDIANA

PREPARED FOR

U. S. ARMY ENGINEER DISTRICT, LOUISVILLE

CORPS OF ENGINEERS

LOUISVILLE, KENTUCKY

BY

U. S. DEPARTMENT OF THE INTERIOR

BUREAU OF OUTDOOR RECREATION

LAKE CENTRAL REGION

OHIO RIVER BASIN OFFICE

LEBANON, OHIO

JANUARY 1964

EXHIBIT F-4

APPRAISAL OF MULTI-PURPOSE PROJECT FOR RECREATION

Preface: The following appraisal is made on the assumption that the plan of operation will not adversely affect the recreation use of the project. It applies to this particular site only and does not constitute a unit evaluation of a proposed system of reservoirs in that possible effects of other sites upon this site have not been considered.

1. PROJECT NAME

Patoka Reservoir

2. LOCATION

The project is located on the Patoka River in Crawford, Dubois and Orange Counties, 14 miles southwest of Paoli and 14.8 miles south of French Lick, Indiana. The dam site is located at river mile 118.3 and about 3/4 mile northeast of Ellsworth, Indiana.

3. GENERAL CHARACTERISTICS OF PROJECT AREA PERTINENT TO RECREATION USE AND DEVELOPMENT

Valleys with narrow flood plains and irregular upland topography are typical in the project area. For the most part, the terrain immediately surrounding the reservoir varies from high flat ridges to rolling or undulating uplands with moderate to steep slopes. Maximum variance of topography within one mile of the site is 270 feet.

The reservoir area is primarily open agricultural lands. Forest cover is limited to the steeper hillsides and ravines. Farm woodlots composed of oak, hickory and related hardwood species are scattered throughout the area.

The project is situated almost entirely within the original defined Hoosier National Forest boundary line.

Access to the project site is fair. North-south mobility is provided by Indiana Highway 145. East-west movement would be improved with the implementation of the proposed program for construction of Interstate 64. Direct access to the immediate area is provided by a network of local hard surface and gravel roads.

4. FEATURES OF THE RESERVOIR AND EFFECTS ON RECREATION

The source of project engineering and operation data is the Louisville District, Corps of Engineers. Project purposes to be served by the reservoir will include flood control, general recreation, fish and wildlife recreation, water supply, and water quality control. The dam will rise to elevation 565 feet 1/, will be a maximum of 89 feet high and about 2,500 feet long, and will control the runoff from a drainage area of 168 square miles.

The reservoir will have three storage pools--minimum, seasonal, and flood control. The minimum pool will be the lowest level to which the water will be drawn. The seasonal pool will be filled each year, as runoff conditions permit, from about early May to early September. At this time the seasonal pool will be gradually withdrawn, augmenting the normally low natural flows and making possible additional flood control storage. Information is not available as to the probable minimum instantaneous flow to be provided by the project nor the probable frequency of drawdown to the minimum pool level in winter. Tentative data concerning the reservoir appear below.

1/ All elevations are in feet and refer to mean sea level datum.

Pool	Elevation (ft.msl)	Capacity (acre-feet)	Surface Area (acres)	Length of Pool (main stream) (miles)
Flood Control	550	324,000	11,760	31
Seasonal	536	180,700	8,880	25
Minimum	506	13,200	2,010	11

The water surface area created by establishment of a seasonal pool at elevation 536 would be compatible with recreation interests and permit orderly and economical development of the available resources. Temporary flood storage above the seasonal pool level would not materially affect the recreation potentialities of the site; however, this factor would have to be considered in the location of permanent facilities such as bathhouse, concession building, and the stabilization of bathing beaches, boat docks and boat launching facilities.

The reservoir, due to irregularity of the topography, would have a diverse shoreline with numerous bays, coves, peninsulas and arms. There would be two distinct arms, one formed by Lick Fork Creek and the main arm formed by Patoka River and Painter Creek. The proposed recreation site located on the north shore of the Patoka River arm, just east of the spillway location, should be utilized for recreation in connection with day use activities and limited overnight camping. A secondary highway, S 1191, provides access to this area.

The proposed site on the west shoreline of Lick Fork Creek has a rather steep terrain with access to the water somewhat limited, but due to location and forest cover, should be utilized for tent camping and organized group camping.

The site situated between the arms of Painter Creek and Patoka River and bounded on the east by route 145 would be suitable for day use as well as tent camping and group camping. The site situated between the arms of Lick Fork Creek and the Patoka River should be developed primarily for tent and group camping, nature trails, and other less intensive uses.

5. REGION SERVED AND POPULATION.

There are no Standard Metropolitan Statistical Areas included within the 50-mile zone of influence. The Standard Metropolitan Statistical Areas of Louisville, Kentucky and Indianapolis, Terre Haute and Evansville, Indiana are located respectively at 55, 100, 85 and 55 air miles distant from the project.

The town of Paoli, population 2,754 (1960 Census), lies 14 miles northeast of the proposed site. Numerous small rural communities are situated adjacent to the site in the predominantly forested area.

A population of 413,000 resides within the 50-mile zone of influence. It is anticipated that this population will increase to 440,000 by 1975 and to 746,000 by the year 2000.

6. RELATED RECREATION AREAS

The reservoir site is located within the administrative boundaries of the Hoosier National Forest. This National Forest is comprised of four purchase units encompassing 772,460 acres of which about 120,000 have been acquired. The German Ridge Recreation Area and Pioneer Mothers Memorial Forest are developed recreation areas within the

National Forest. During 1958, about 12,000 people used these facilities. Lincoln Boyhood National Memorial Monument is within the 50-mile zone of influence.

Two State Park Areas, Spring Mill and Lincoln State Parks, provide 2,750 recreation acres within the zone. In 1960 there were 273,654 visits to these areas.

Three State Forests--Ferdinand, Martin and Starve Hollow--provide an additional 11,550 recreation acres within the zone. State Forest visitation is unknown.

7. TYPES OF RECREATION FOR WHICH THE PROJECT IS SUITED

Prime value for this reservoir exists in the fact that no other large impoundment is available for water oriented recreation within the zone of influence. The overall size of the impoundment, relatively high ratio of shoreline miles to water acreage, scenic topography, low population density, and location within the administrative boundary of the Hoosier National Forest are a combination of features not often found at proposed project areas. The large impoundment and attractive terrain would be suitable for a wide variety of recreation uses. Boating, picnicking, camping and hiking would be popular activities.

8. RECOMMENDED PLAN OF DEVELOPMENT

The Patoka Reservoir will have the inherent capacity to fulfill public water oriented recreation needs in the zone of influence. However, as a prerequisite to fulfilling these needs it will be necessary

to acquire and develop about 4,000 acres of lands adjacent to the reservoir, essentially as shown on the attached map. The Forest Service and the Indiana Department of Parks have both indicated interest in the administration of recreational lands at the project. Additionally, in order to assure optimum utilization of the reservoir recreation potential, several minimum public access sites will need to be developed. The plan of improvement outlined below includes initial and deferred plans of development.

A. Initial Plan

(1) Purpose

The protection and development of the recreation potential of the project site and the meeting of immediate needs for recreation in the area of influence would be the prime goals of facilities to be developed in the initial plan 2/. This plan should be developed to accommodate a design load of 7,700 and an estimated annual attendance of 400,000 visitor days. Initial development would be directed primarily to day use recreation activities with limited overnight camping.

(2) General Description

A 570 acre area located on the north shore of the reservoir and just east of the spillway would provide for a major portion of day use facilities. An area of 530 acres situated on the west shore of the Lick Fork Creek arm should be utilized for tent camping and any organized group camping to be included in initial development. The 1540 acre

2/ First five years following project construction.

site which lies between Painter Creek and Patoka River should be developed initially on a limited scale to include both day use and overnight camping facilities. Day use development in this stage would consist of boat launching sites, picnicking and beach facilities.

B. Deferred Plan

(1) Purpose

The deferred plan of improvement would be designed to provide facilities for optimum use expected. The recreation activities provided for under this plan would include expansion of swimming, picnicking and boating facilities. The establishment of hiking, nature trails, camping and overnight facilities, trailer areas, cabin areas and organized group camp areas would be accomplished in this phase. When completed, the project recreation lands would be developed for a maximum design load of 25,700 and an estimated optimum utilization of 1,350,000 visitor days of general recreation.

(2) General Description

Development in this stage would proceed with expansion of facilities initiated in the previous stage. Additionally, the 1360 acre area between Licking Fork Creek and Patoka River should be developed during this stage in order to meet the anticipated ultimate visitation to the project. Major emphasis would be given to group uses such as cabin area, trailer area, group camp use and organized group camps. Bathing and boat launching facilities would need to be provided to service these operations.

9. BENEFITS

Monetary evaluations of general recreation are in general accordance with the October 31, 1963 draft of "Evaluation Standards for Primary Outdoor Recreation Benefits," as prepared by the Joint Task Force on Recreation of the Recreation Advisory Council and the Ad Hoc Water Resources Council. This procedure is used to evaluate benefits which accrue to general recreation as a result of construction of the proposed project.

In the following table the estimate of optimum visitation (50th year) to the project indicates the maximum number of visitor-days per year expected to occur at public recreation facilities. The average annual net monetary benefits are provided for use in determining the benefit/cost ratio.

ESTIMATES OF OPTIMUM AND AVERAGE ANNUAL

VISITATION AND VALUES OF PUBLIC RECREATION AT PATOKA RESERVOIR

Year	Recreation Days	Benefit Value	Recreation Benefits
5	400,000	$1.00	$ 400,000
50	1,350,000	$1.50	$2,025,000
Avg. Ann. 50-year	808,000	$1.45	$1,172,000
Avg. Ann. 100-year	1,079,000	$1.48	$1,597,000

10. RECREATION DEVELOPMENT COSTS

The estimated recreation development costs for initial, deferred and total recreation development are shown in the following table. These amounts do not include the cost of land acquisition.

RECREATION DEVELOPMENT COSTS

	Initial	Deferred	Total
Facilities	$1,418,000	$2,695,000	$4,113,000
Planning, Overhead and Contingencies	354,000	674,000	1,028,000
	$1,772,000	$3,369,000	$5,141,000

The total annual equivalent of construction costs for recreation facilities is based on a 25-year period at 2-7/8%. This figure is currently used for what is considered as the life of recreation facilities for the project and is shown as follows:

ANNUAL CHARGES RELATED TO CONSTRUCTION
OF RECREATION FACILITIES

	Initial	Deferred	Total
Operation & Maintenance	$ 80,000	$190,000	$270,000
Annual Equivalent of Construction Costs	100,000	191,000	291,000
	$180,000	$381,000	$561,000

11. RECOMMENDATIONS

A. General recreation should be included as one of the purposes for which the project is authorized.

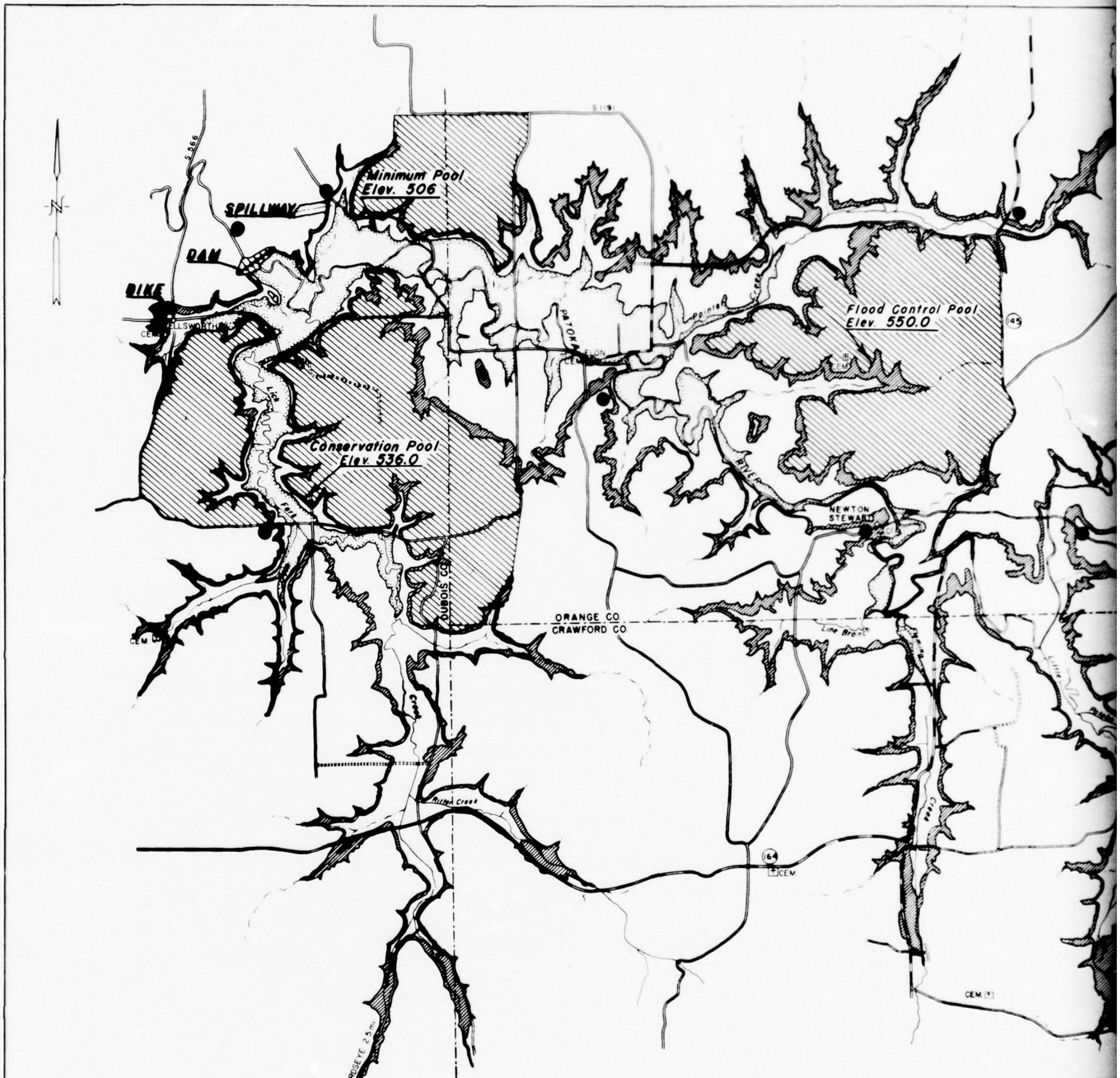
B. Approximately 4,000 acres of land, located substantially as shown on the attached map, should be acquired in fee simple at project cost for general recreation. The responsibility for the development and administration of the recreation use of these lands should be vested in the Forest Service or the Indiana Department of Conservation.

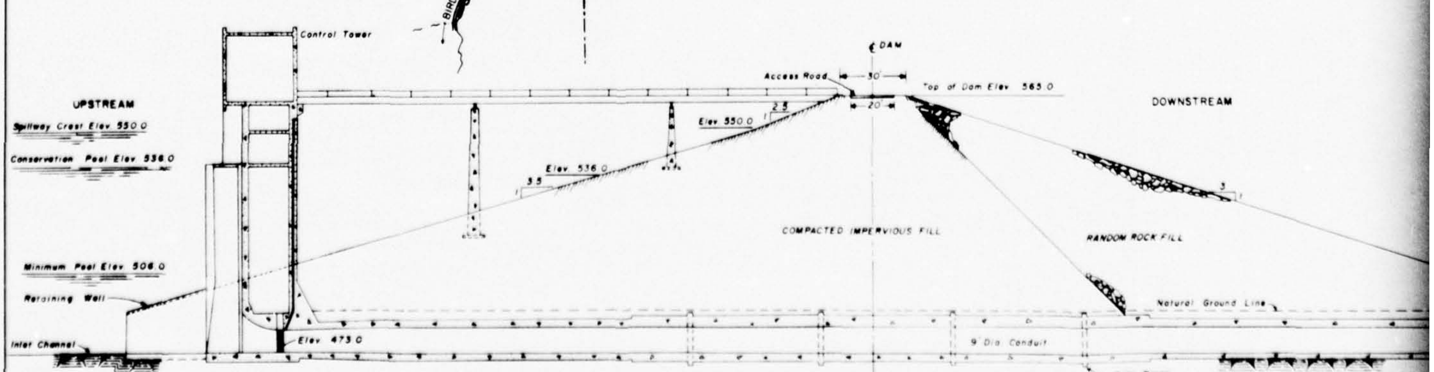
C. All minimum facility public access sites shown on the attached map should be provided at project cost.

D. Consideration should be given to the development of a zoning plan for project lands and waters to insure that optimum opportunities for general recreation may be realized without conflicting with fishing, hunting, and associated wildlife purposes; such zoning plan to be developed cooperatively by the Corps of Engineers, the Bureau of Outdoor Recreation, the Bureau of Sport Fisheries and Wildlife, the Forest Service, and the Indiana Department of Conservation.

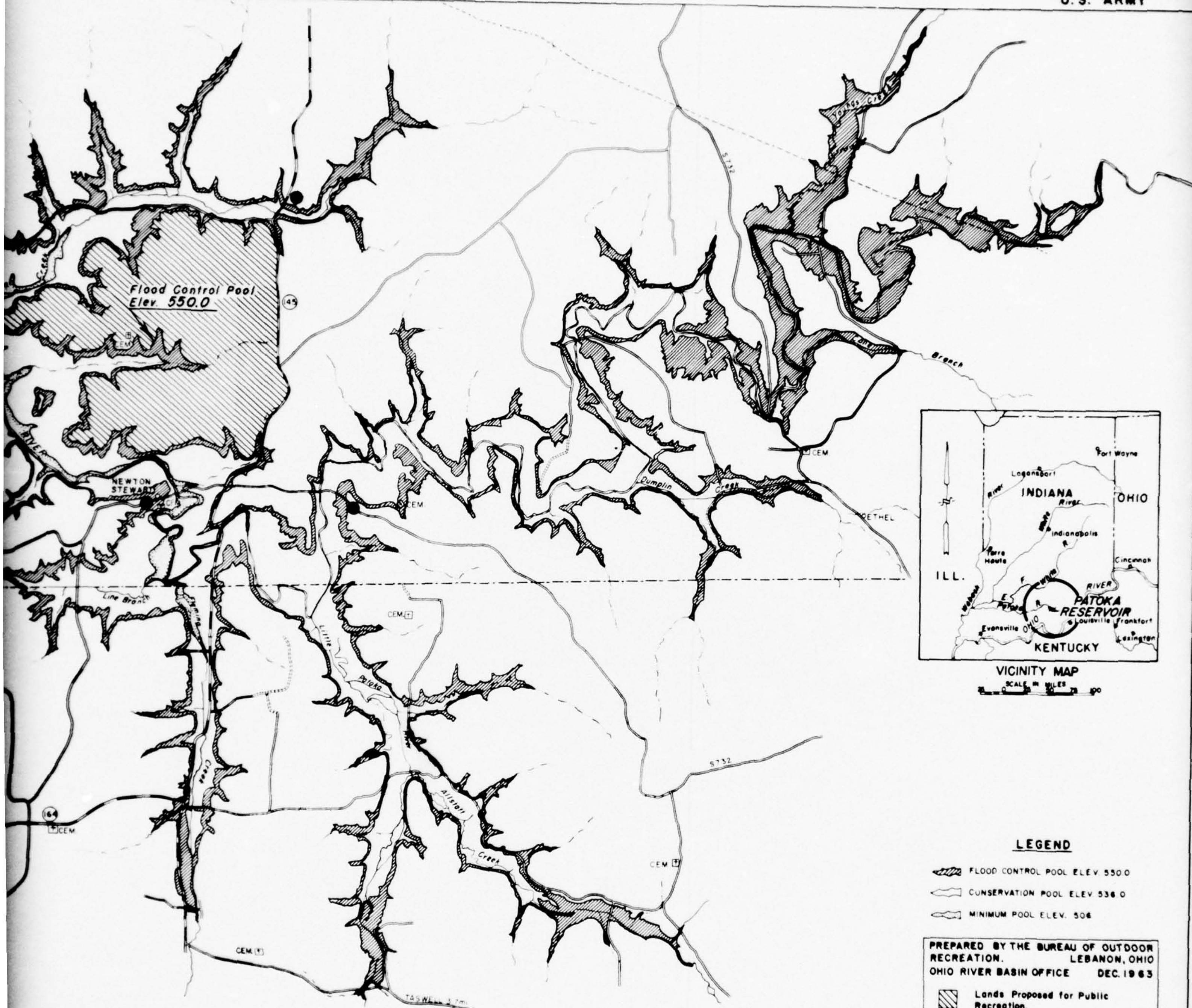
E. The report of the District Engineer should recognize the need for additional recreation studies and should provide for such reasonable modifications, including the extent and location of recreation lands, as may be agreed upon by the same agencies as named in the previous paragraph.

CORPS OF ENGINEERS





SECTION OUTLET WORKS AND EMBANKMENT



LEGEND

FLOOD CONTROL POOL ELEV. 550.0

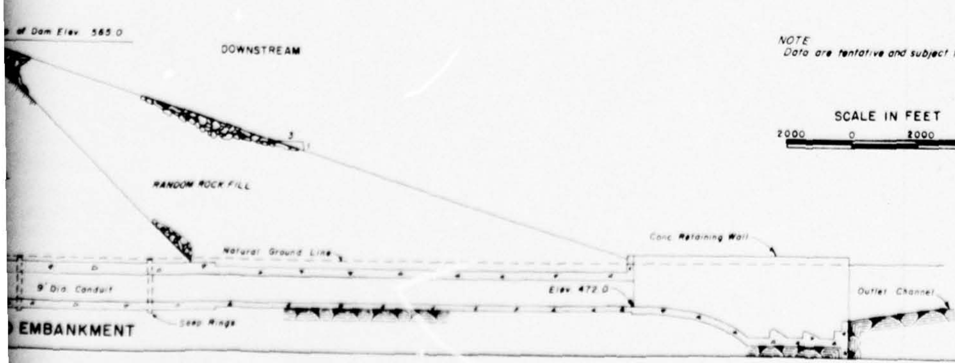
CONSERVATION POOL ELEV. 536.0

MINIMUM POOL ELEV. 506

PREPARED BY THE BUREAU OF OUTDOOR RECREATION. LEBANON, OHIO
OHIO RIVER BASIN OFFICE DEC. 1963

Lands Proposed for Public Recreation.

Minimum Public Access Sites.



NOTE
Data are tentative and subject to revision

SCALE IN FEET
2000 0 2000 4000

PLAN CONSIDERED FOR PATOKA RESERVOIR

PATOKA RIVER, INDIANA

LOUISVILLE DISTRICT DECEMBER 1963

2

COPY

STATE of INDIANA

INDIANAPOLIS

Department of Conservation

March 3, 1964

Mr. Roman H. Koenings, Regional Director
U. S. Department of the Interior,
Bureau of Outdoor Recreation
15 Research Drive
Ann Arbor, Michigan 48103

Dear Mr. Koenings:

Reference is made to your letter of February 27th concerning your preliminary reports on recreation potentials at Patoka and Clifty Creek Reservoirs.

Immediately following receipt of your letter these reservoir areas and proposed recreation lands were plotted on U. S. G. S. maps, and the reports were reviewed by members of my staff. We concur in the recommendations relating to land acquisition development, multiple use and to cooperation and coordination between the interested agencies mentioned.

We believe that additional studies of land acquisition may well disclose a limited, yet desirable, extension of land tracts proposed for general recreation use. We believe that in the case of Patoka Reservoir; due to its extent and proposed multiple use, close cooperation and coordination would be necessary between the interested agencies, and we suggest that a clear determination of a development and operational planning schedule be established as soon as practicable.

The Indiana Department of Conservation would be interested in receiving, under agreeable terms, an operational and administrative license for the development and operation of these two reservoirs.

Very truly yours,

/s/ Donald E. Foltz
Donald E. Foltz, Director
Department of Conservation

DEF:fd

EXHIBIT F-4

COPY

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Wayne-Hoosier National Forests
BEDFORD, INDIANA

March 3, 1964

Mr. Roman H. Koenings
Regional Director
Bureau of Outdoor Recreation
15 Research Drive
Ann Arbor, Michigan 48103

Dear Mr. Koenings:

We have reviewed your preliminary report on the Patoka Reservoir and are in substantial agreement with your findings. There is only one small correction at the top of page 2; the project is mostly, but not entirely, within the national forest boundary (see map attached).

We feel that development and administration of these project-related public lands would be most effectively and economically accomplished by placing these lands under the jurisdiction of a single public land management agency. Because the Forest Service already has an effective administrative structure established in the area, and because they presently administer lands which would adjoin project lands, we recommend that all lands above the seasonal pool at elevation 536 be incorporated into the Hoosier National Forest system. Transfer of these lands can be accomplished under provisions of the Act of July 26, 1956 (70 Stat. 656; 16 U. S. C. 505a, 505b) which states that "The Secretary of Agriculture with respect to national forest lands and the secretary of a military department with respect to lands under control of that department which lie within or adjacent to the exterior boundaries of a national forest are authorized . . . to interchange such lands . . . without reimbursement or transfer of funds whenever they shall determine that such interchange will facilitate land management and will provide maximum use thereof for authorized purposes . . ." Inclusion of these lands in the present national forest system would provide for optimum development of project-related soil, water, timber, fish and wildlife, and recreation resources which would accrue additional benefits to the project.

We realize that it was not your intent to recommend a recreation administering agency in this preliminary report. However, we intend to build a very strong case for Forest Service participation and hope that you will agree.

We will appreciate being kept advised on this project and will be glad to assist you in any way we can.

Sincerely,

Sgd/Howard C. Cook

HOWARD C. COOK
Forest Supervisor

Enclosure

Exhibit F-4

COPY

MINERAL RESOURCES AT LINCOLN RESERVOIR SITE
COLES, DOUGLAS, AND CUMBERLAND COUNTIES, ILL.

By L. F. Heising
Bureau of Mines
November 1963

Exhibit F-5

MINERAL RESOURCES AT LINCOLN RESERVOIR SITE,
COLES, DOUGLAS, AND CUMBERLAND COUNTIES, ILL.

By

L. F. Heising 1/

CONTENTS

ILLUSTRATIONS

1/ Supervising Mining Engineer, Bureau of Mines, Area III, Minneapolis, Minn.

SUMMARY AND CONCLUSIONS

Mineral commodities produced in Coles, Douglas, and Cumberland Counties are (1) limestone, (2) sand and gravel, and (3) coal. The reservoir area lies about midway between two oil pools that are approximately 20 miles apart.

Limestone quarries producing products valued at $566,000 in 1962 will be inundated at the 629-foot flood control level. Waste stripping could be used by quarry operators to form dikes which would provide protection at seasonal reservoir levels and during minor flood conditions. Consideration should be given to obtaining flowage easements for quarry areas; if agreeable to operators.

No strip coals occur in the reservoir area. The estimated depth of the top coal bed is 960 feet. The overburden over the coal is adequate and sufficiently competent to permit mining under the reservoir provided adequate safeguards are utilized.

Dry holes drilled in the reservoir area indicate lack of oil potential.

INTRODUCTION

Mineral resources at the proposed Lincoln Dam and Reservoir sites were investigated in September 1963 at the request of the Corps of Engineers, Louisville District. The investigation included field reconnaissance, consultation with State and Federal officials, and collecting information obtained from literature and resource maps published by State and Federal agencies.

LOCATION AND ACCESSIBILITY

The Lincoln damsite is about one-third mile south of the Coles-Cumberland County line on the Embarrass River, sec. 27 T. 11 N., R 9 E., 3rd principal meridian. The reservoir waters will approach the town limits of Charleston, the county seat of Coles County (fig. 1). Other cities and towns in the vicinity of the reservoir include Ashmore, Oakland, and Hindsboro. The area is readily accessible by paved state and county highways and graveled roads.

PHYSICAL FEATURES

The Embarrass River will form a reservoir north of the damsite with a total area of 21,250 acres when the flood control level reaches the 629 mean sea level spillway elevation. Minimum pool elevation is proposed at 584 feet; seasonal pools will range between 584 and 596 feet. Drainage area of the proposed reservoir is 915 square miles.

The reservoir will be enclosed by rounded low hills covered with Pleistocene till, outwash, and loess. The area that would be inundated consists mainly of agricultural lands, rural roads, and patches of tree and brush-covered woodland.

GEOLOGY

The geology of this area is best described by Clegg.2/ The geology of Cumberland, Coles, and Douglas Counties is complex both stratigraphically and structurally (figs. 2 and 3). Two major and several minor structural features have had a pronounced effect upon the sedimentational history of the three counties, and have added to the complexity of correlation and interpretation of geologic history.

During the Pleistocene epoch three great continental ice sheets, the Kansan, Illinoian, and Wisconsin advanced from Canada and retreated, leaving widespread glacial deposits.

The Pennsylvanian System in Coles and Cumberland Counties consists of the McLeansboro, Carbondale, Tradewater, and Caseyville groups, named in increasing age (fig. 4). These bedrock formations are layers of limestone, shale, sandstone, dolomite, and coal.

MINERAL RESOURCES

Coal 3/

Past exploration of the coal resources of Coles, Douglas, and Cumberland Counties was limited to those coal measures below the top of the Millersville limestone. Except for a few exposures of the Millersville and adjacent beds, the Pennsylvanian strata is covered by drift.

Most of the published data on coal bed extent and depth was gained from drill logs of oil well test holes.

The only coal production in Coles and Douglas Counties has been from the No. 7 coal of the McLeansboro group (fig. 4). There has been no production in Cumberland County. The deeper coals of the Carbondale group have not been utilized. The No. 7 coal was located in electric logging an oil drill hole at a depth of 960 feet in sec. 4, T. 11, R. 9 E. One available diamond drill hole in sec. 36, T. 16 N., R. 7 E. showed the No. 7 coal to be only 7 inches thick. At the abandoned Mattoon Mine; sec. 14, T. 12 N., R 7 E., Coles County, the No. 7 coal was of minable thickness, 42 inches and 904 feet deep.

2/ Clegg, Kenneth E. Subsurface Geology and Coal Resources of the Pennsylvanian System in Douglas, Coles, and Cumberland Counties, Illinois. Illinois Geol. Survey Circular 271, 1959, 16 pp.
3/ Work cited in footnote 2.

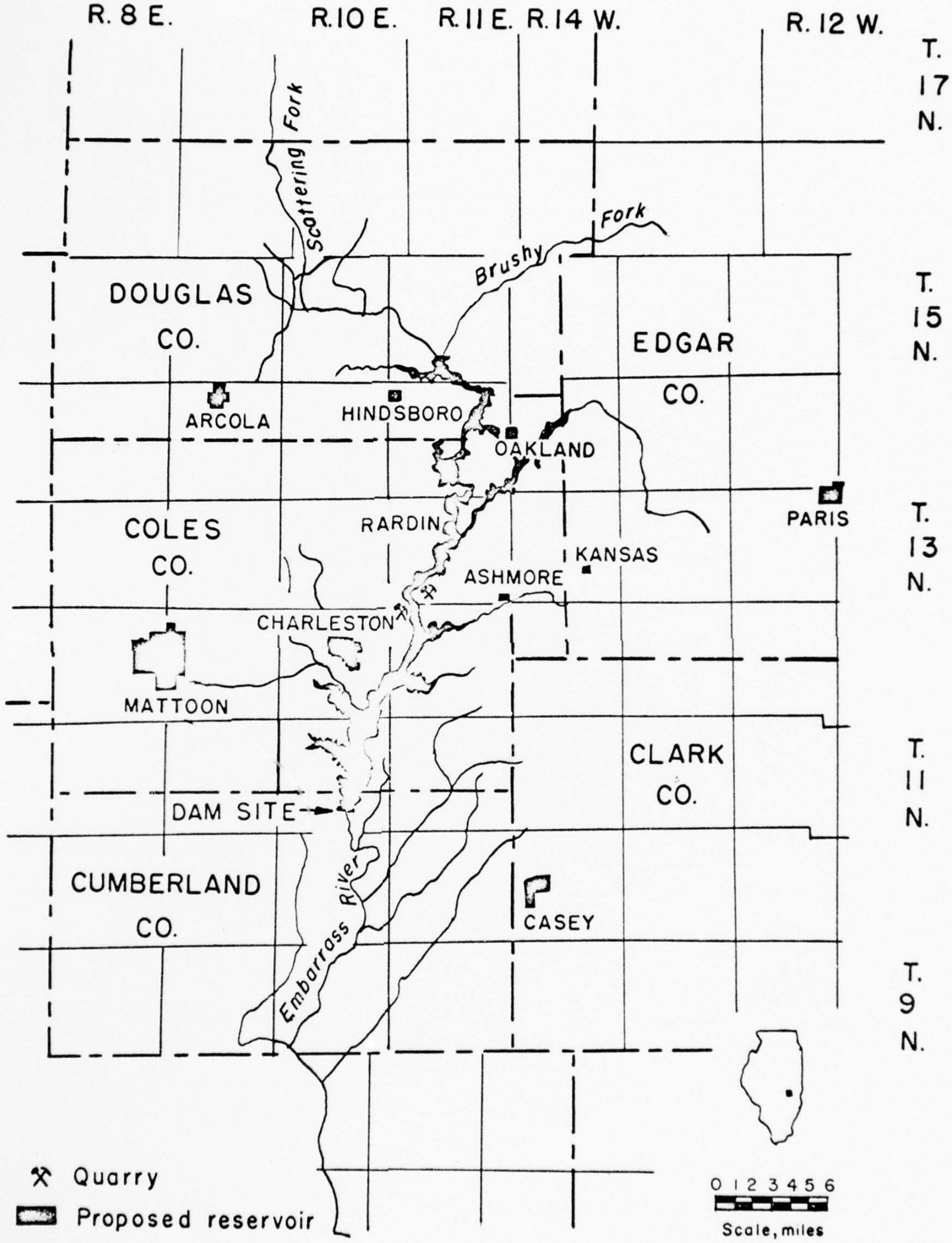


FIGURE 1 Location Map

Lincoln Reservoir Area

Exhibit F-5

FIGURE 2. - Index map showing location of Douglas, Coles, and Cumberland Counties with reference to the deep part of the Illinois Basin.
(Source: Circular 271, Illinois State Geol. Survey, 1959.)

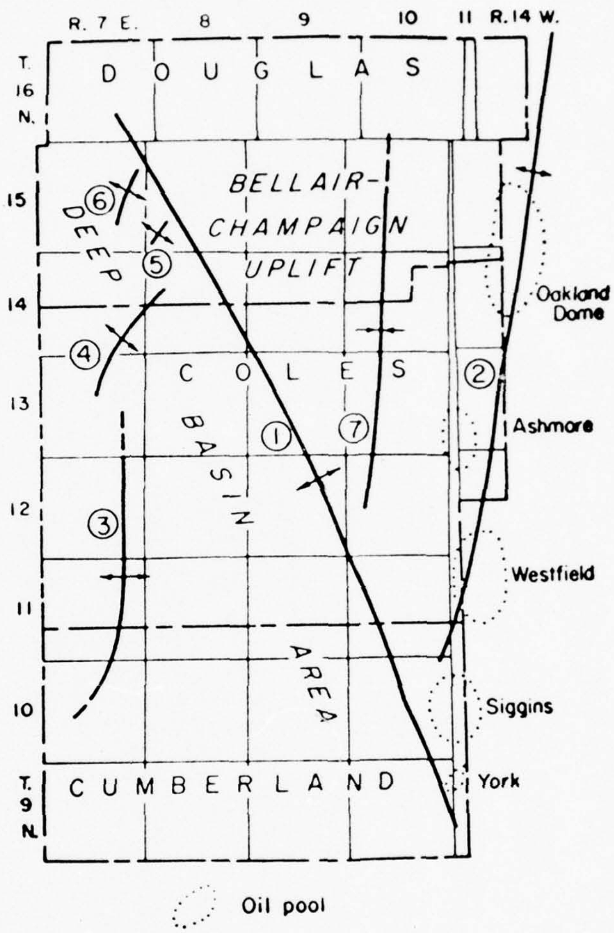


FIGURE 3. - Index map showing location of principal structural features in Douglas, Coles, and Cumberland Counties.

1. LaSalle Anticlinal Belt
2. Oakland Anticlinal Belt
3. Mattoon Anticline
4. Cooks Mills Anticline
5. Chesterville structure
6. Bourbon structure
7. Murdock Syncline

(Source: Circular 271, Illinois State Geol. Survey, 1959.)

Exhibit F-5

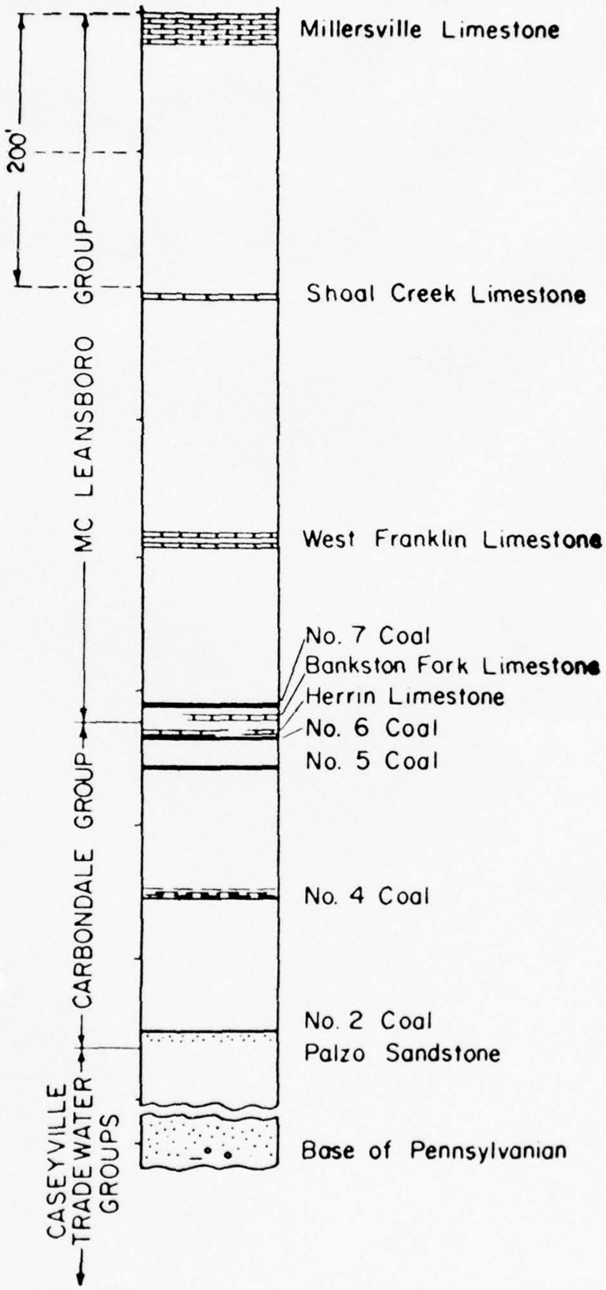


FIGURE 4. - Generalized columnar section of the Pennsylvanian strata below the Millersville Limestone in the deep basin area of Cumberland and Coles Counties.

(Source: Circular 271, Illinois State Geol. Survey, 1959.)

Exhibit F-5

Coals of the Carbondale group below the No. 7 coal in the deep basin area of Coles and Douglas and Cumberland Counties appear to be less than 3 feet thick and lie at depths greater than any current coal mining in Illinois.

The coal is presently not commercial because of the easy availability of other deposits that can be mined at lower cost. Mining of these deposits will likely be deferred until after the more available supplies are exhausted, which would be quite a long time in the future, in the light of present knowledge.

Limestone

The Millersville limestone is quarried along the Embarrass River Valley northeast of Charleston in secs. 5 and 32, T. 13 N., R. 10 E. The formation's general dip is southward. The limestone, approximately 20 feet thick, is quarried by two companies, the Charleston Stone Co. and Olen Humphres Stone Quarry.

Both operations are situated along the river with the Charleston Quarry plant near the west river edge and Humphres' on the east side of the river. Quarry workings extend for about one mile along the river banks.

The Charleston Stone Co. plant site is shown at 610 feet mean sea level on the State Waterway Commission topographic survey map of the river. Olen Humphres' plant will not be reached by flood waters.

The bottom elevation of the limestone is about 590 feet. The road into the Charleston Quarry is at this elevation and rises to about 610 feet in the plant area. Proposed seasonal pool elevation of the reservoir will range from 584 to 596 feet.

In the present operating portion of the Charleston Quarry overburden stripping has been placed on the river bank side of the quarry. This, in effect, provides the start of a dike system that could protect the quarry from flooding. The stripping banks are presently pierced to allow drainage from the quarries. These holes in the stripping banks could be filled to form dike protection.

A low dike presently protects Humphres' operations. This dike could be raised using stripped material to protect the operation during all except severe flood conditions. Flood conditions expected by Corps of Engineers are as follows: 629 feet once in 80 years; 616 feet once in 20 years; and 605 feet once in 5 years.

In view of the expected flood conditions and the ability of the operators to provide stripping waste to partially protect these operations, it is recommended that consideration be given to flowage easements in lieu of obtaining these lands in fee.

The quarries using waste stripping could provide protection for normal seasonal pool elevations and minor flooding, but not extreme flood conditions.

The quarries are an important source of agricultural limestone. The quarries produced 360,000 tons of crushed and agricultural limestone valued at $566,000 in 1962. Employment at the quarries averages 43 persons for 290 days per year.

In the event that flowage easements were impractical or not acceptable to the operators, the quarries' operations should be continued as long as possible to enable development of alternate sources of limestone. It is expected that operating costs at alternate higher elevations would be higher due to the expense of removing additional overburden.

Oil and Gas

Published maps of the Illinois Geological Survey 4/ show that the proposed reservoir lies midway between the Mattoon and Westfield oil and gas pools which are approximately 20 miles apart. Several smaller oil pools parallel the reservoir area about 8 miles to the east. Oil production is from strata of Pennsylvanian, Mississippian, and Devonian age.

There is no oil or gas production in the reservoir site.

The large number of dry holes plotted on the published oil and gas development maps of the area indicate the area to be inundated is not favorable for oil and gas production.

Sand and Gravel

The main sources of sand and gravel in the reservoir area are to be found in the Embarrass River Valley and consist of eskers and terraces formed during the Pleistocene epoch. Many of these deposits are considered capable of development or deserving of being prospected. Although a number of these potential undeveloped sand and gravel sources will be inundated, alternate sources at elevations higher than reservoir level will be available for exploitation.

Olen Humphres operates a sand and gravel pit in conjunction with his limestone operations in sec. 32, T. 13 N., R. 10 E. The pit is presently protected from the river by a small dike. Dikes established to protect this deposit would in part also protect Humphres' limestone quarry.

4/ Oil and Gas Development Map, Oakland Area.
Oil and Gas Development Map, Charleston Area. Illinois State Geol. Survey.

MINERAL PRODUCTION

Minerals produced in Coles County in 1962 were valued at $686,367, exclusive of oil and gas production. Oil produced in 1961 was 454,000 barrels valued at $1,360,000. Sand and gravel valued at $118,809 was produced by four companies. The Mattoon area produced 70 percent of the total sand and gravel.

Limestone was produced by Charleston Stone Co. and Olen Humphres in the Embarrass River Valley northeast of Charleston. Plant products were used as crushed limestone for road paving and agricultural purposes. These quarries represent 83 percent of the value of minerals produced in Coles County.

Mineral production of Douglas County was primarily coal, with a value of over $2 million. As there is only one producer, the Moffat Coal Co. near Murdock, exact production and value cannot be disclosed.

In 1961, 220,000 barrels of oil were produced, valued at $660,000.

Mineral production of Cumberland County, with the exception of oil and gas in 1962, was $155,000. The value of oil production is combined with Clark County, in State production values, to avoid disclosing confidential data. In 1961 Clark and Cumberland Counties produced 1,255,000 barrels, valued at $3,675,000.

COPY

MINERAL RESOURCES AT CLIFTY CREEK RESERVOIR SITE, BARTHOLOMEW COUNTY, IND.

By L. F. Heising
Bureau of Mines
November 1963

Exhibit F-5

MINERAL RESOURCES AT CLIFTY CREEK RESERVOIR SITE, BARTHOLOMEW COUNTY, IND

By

L. F. Heising 1/

CONTENTS

ILLUSTRATIONS

1/ Supervising Mining Engineer, Bureau of Mines, Area III, Minneapolis, Minn.

SUMMARY AND CONCLUSIONS

The Clifty Creek Reservoir is in an area of little mineral potential. There are no known surface mineral deposits other than limestone and sand and gravel. The limestone and sand and gravel deposits are not commercial because ample developed supplies are available closer to the more populous communities near the reservoir site.

The Trenton Limestone that has produced oil and gas is known to occur beneath the reservoir. The test holes drilled in the area were dry holes. The weight of evidence indicates that oil reserves do not exist beneath the reservoir site. The possibilities of future important gas production from reservoir lands is considered remote.

INTRODUCTION

The Clifty Creek damsite is in east central Bartholomew County, Indiana, on Clifty Creek, in sec. 2, T 9 N, R 7 E (fig. 1). The reservoir waters will approach the town limits of Hartsville. No other cities and towns are in the immediate vicinity of the reservoir area. State road No. 46 crosses the damsite at Fall Fork and will be inundated in the reservoir area from the damsite almost to Hartsville. Columbus, a town of 20,788 population lies about 13 miles west of the reservoir area.

PHYSICAL FEATURES

Clifty Creek will form a reservoir starting from the damsite at the intersection of Clifty Creek and Fall Fork with a total area of 1,330 acres when the storage level reaches 730 feet mean sea level, sea level spillway elevation. Drainage area of the proposed reservoir is 140 square miles.

The reservoir will occupy a relatively steep walled stream valley at the damsite. The topography changes to flatter rounded hills upstream. Brush and trees cover the valley walls. Agricultural land at the reservoir site is being used for growing corn and hay.

MINERAL PRODUCTION

Minerals produced in 1962 in Decatur and Bartholomew Counties were valued at $1.3 million and consisted of crushed limestone and sand and gravel. The major producer is the Meshberger Stone Corp. which operates a limestone quarry near Elizabethtown, about 8 miles southwest of the reservoir area (fig. 1).

There is no mineral production of record from the lands proposed as the reservoir site.

GEOLOGY 2/

The general topography in the proposed Clifty Creek Reservoir area is gently rolling to where Clifty Creek and Fall Fork meet; here the drift is deeply dissected and the creek valley wall becomes quite steep. Relief in the area of the reservoir ranges from 670 to 780 feet.

The reservoir lies within the Till Plains section of the Central Lowlands province. Although the area has been glaciated, the drift is thin (0 to 30 feet), and bedrock controls the topography. Bedrock in the area (fig. 2) consists of Devonian and Silurian limestone, and dolomites gently dipping 15 to 20 feet per mile to the southwest into the Illinois Basin. The geologic column of the bedrock is shown in fig. 3.

Published records of well drilling about 5 miles east of the reservoir, in sec. 17, T 10 N, R 7 E, Bartholomew County show the formations as follows: 3/

Drift to	12	feet
Fresh water	80	do.
Limestone	112	do.
Shell limestone	500	do.
Brown shale	853	do.
Shell, Trenton	855	do.
Total depth	905	do.

In the reservoir area, Clifty Creek has cut through the overlying glacial drift and Devonian limestone to expose Silurian limestones of Niagaran age in the floor of the creek valley.

2/ Murray, H. H., Sedimentation and Stratigraphy of the Devonian Rocks. Field Conference Guide Book No. 8, 1955, 73 pp.

3/ Logan, W. N., The Subsurface Strata of Indiana. Dept. of Geology, Indiana Dept. of Conservation, 1931, p. 35.

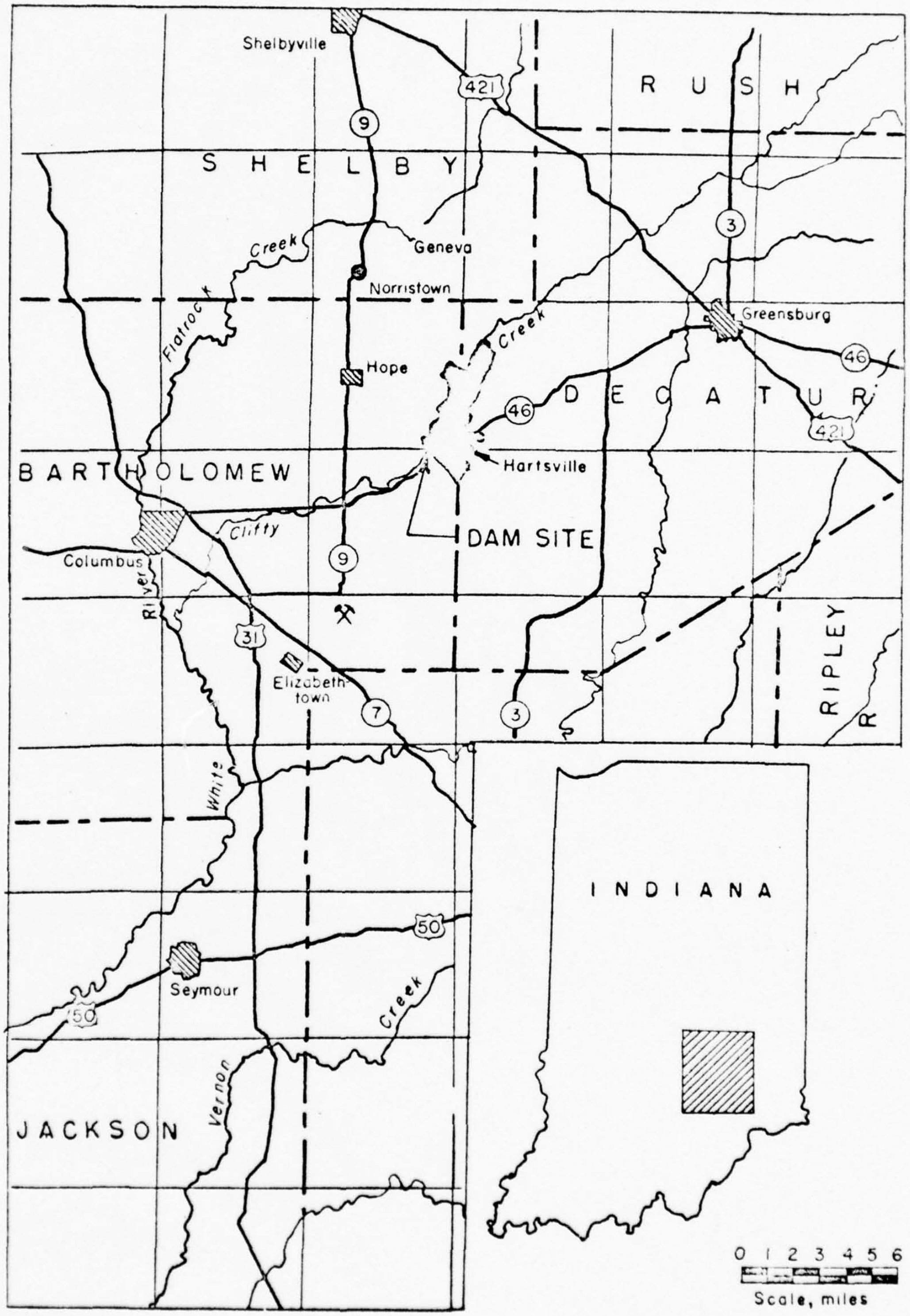


FIGURE 1 Location Map
Clifty Creek Reservior

Exhibit F-5

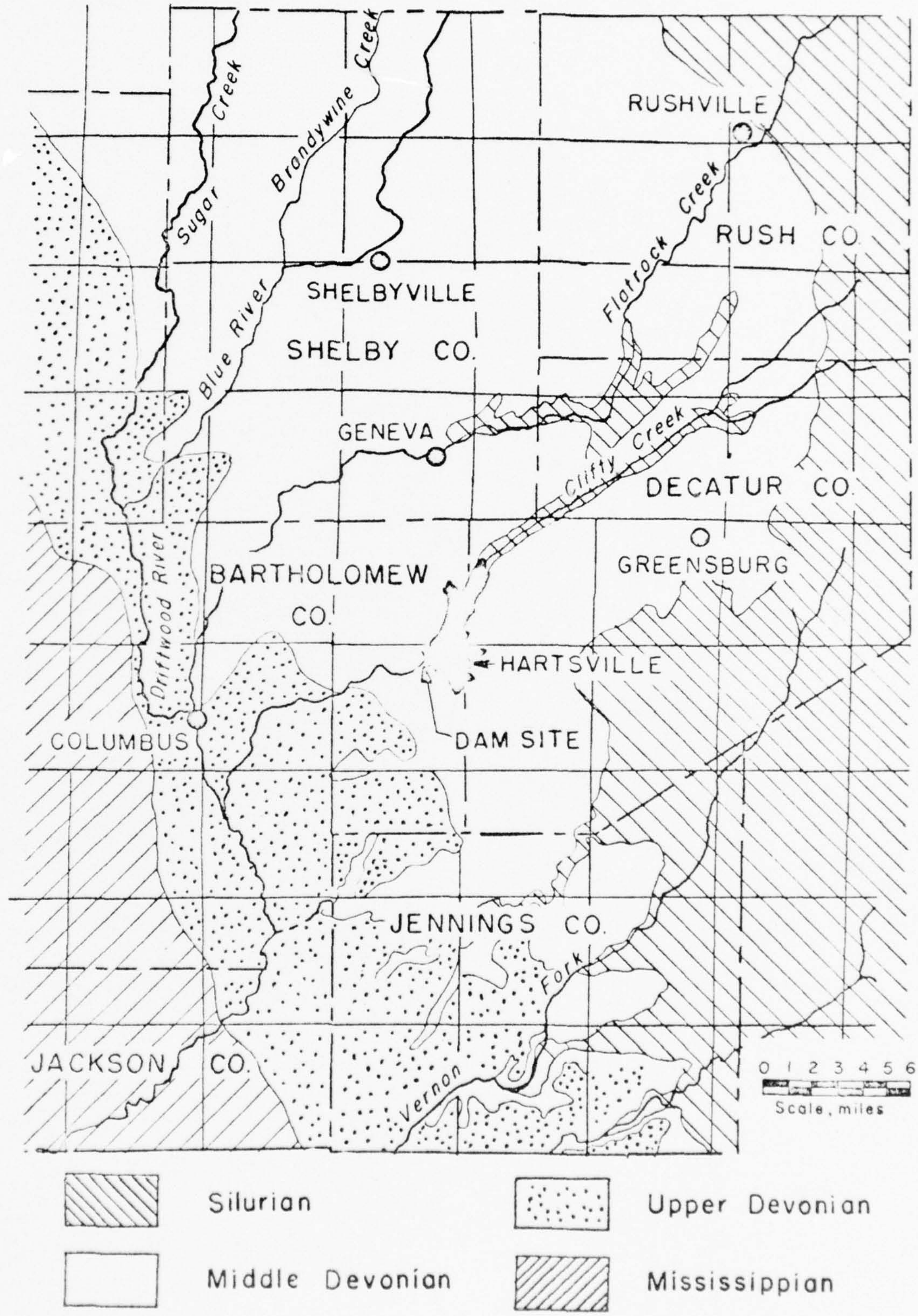


FIGURE 2 Geology Map
Clifty Creek Reservior

Exhibit F-5

<table>
<tr><th>System</th><th colspan="2">Series</th><th>Rock Unit</th></tr>
<tr><td>Genezoic</td><td colspan="2">Pleistocene</td><td>Drift
0 - 30'</td></tr>
<tr><td rowspan="3">Devonian</td><td rowspan="3">Middle</td><td>Erian</td><td>Sellersburg (North Vernon) Ls.
1 - 26'</td></tr>
<tr><td rowspan="2">Ulsterian</td><td>Jefferson Ls.
26 - 46'</td></tr>
<tr><td>Geneva Dol.
0 - 35'</td></tr>
<tr><td rowspan="5">Silurian</td><td colspan="2" rowspan="5">Niagaran</td><td>Louisville Ls.
0 - 52'</td></tr>
<tr><td>Waldron Sh.
0 - 15'</td></tr>
<tr><td>Laurel Ls.
27 - 55'</td></tr>
<tr><td>Osgood Fm. 10 - 30'</td></tr>
<tr><td>Brassfield Ls. 0 - 12'</td></tr>
</table>

FIGURE 3. - General Geologic Column of Clifty Creek Reservoir Area.
Source: Indiana Geologic Survey.

MINERAL RESOURCES

Sand and Gravel

Residual soils, silt, and loess range from 0 to 30 feet in depth. Pleistocene gravels were observed in parts of the creek bottom. These deposits have no particular commercial importance because sufficient supplies of sand and gravel are available in the more populous parts of the surrounding area. The value of sand and gravel deposits are determined by commercial usage and local requirements. Sand and gravel produced from pits in the surrounding area sells for about $1.00 per yard, washed and screened at the pit.

Limestone

The Devonian and Silurian rocks that comprise the bedrock of the reservoir area are predominantly limestones and dolomites. The limestones present are not considered commercial, because of the great extent of available limestone in the State. Limestone, unless developed by quarries, has no particular economic value. Surface land use determines land value.

Oil and Gas

The test holes drilled in the reservoir area are plotted as dry holes on the State Geological Well Location map of Bartholomew County.4/ Gas production has come from wells within 2 miles to the east of the reservoir area. These old wells produced from the Trenton field. Production from the Trenton field has been negligible for the past 40 years.

Entrapment of oil in the Trenton field appears to be a function of changing permeability and structural control. Oil was found only in the upper dolomitized parts of the Trenton limestone of Ordivician age. In the reservoir area this dolomitic phase is thin or absent.5/

4/ Well Location Map of Bartholomew County, Revised 1963. Indiana Dept. of Conservation, Geological Survey.

5/ Gutstadt, A. M., Cambrian and Ordivician Stratigraphy and Oil and Gas Possibilities in Indiana. Indiana Geol. Survey Bull. No. 14, p. 97.

The reservoir area is at the edge of the old non-commercial home gas producing area of the Trenton field. The possibilities of future important gas production is small.

Evidence does not support the occurrence of oil reserves beneath the reservoir.

Coal

There is no coal beneath the reservoir area. The eastern-most extent of Pennsylvanian rocks is 70 miles west of the reservoir area.

WABASH RIVER BASIN

REVIEW OF MINERAL RESOURCES, PATOKA RESERVOIR, DUBOIS, ORANGE, CRAWFORD COUNTIES, INDIANA

By

L. F. Heising[1/]

GENERAL

The Patoka Reservoir site lies in eastern Dubois, southwestern Orange, and northwestern Crawford County with the dam site near Ellsworth, eastern Dubois County, Indiana.

The total drainage area above the proposed dam is 168 square miles with a reservoir area of 11,760 acres at a 550-foot elevation spillway crest. Settlements in the area include the town of Jasper and the villages of Dubois, Birdseye, Eckerty, and Taswell, and a number of small settlements.

Mineral commodities produced from the counties in which the reservoir will be located are (1) coal, (2) clays, (3) stone, (4) abrasives, and (5) sand and gravel. Other mineral commodities produced within a 20-mile radius of the reservoir are gypsum and oil.

Potential mineral resources that will be inundated by the reservoir are limestone, gypsum, and possibly oil. As there is no production of these commodities in the area to be inundated, they can be considered only as a future potential resource. The limestone rocks, unless developed by a quarry, have no special value because of the extent of these rocks in the State providing the possible sources. In limestone areas, the surface land use determines land worth. Drillings for oil have indicated that gypsum beds underlie the reservoir area; but as there are other areas in the State having large gypsum deposits of greater potential, the beds that underlie the proposed reservoir, for valuation purposes, should not be considered of particular importance. The explorations for oil in the immediate reservoir area have not been successful, although there is oil production in the vicinity. In view of the number of dry holes drilled, oil potential in the immediate reservoir area is not considered significant.

1/ Supervising Mining Engineer, Area III Mineral Resource Office Bureau of Mines, Minneapolis, Minn.

Report submitted October 10, 1963

The specific relationship of the above commodities to the reservoir area will be discussed in later sections of this report. The data contained in this report is based mainly on published and unpublished geologic reports, consultation with State Geological Survey personnel, Bureau of Mines statistical data, and an on-site visit to the reservoir area.

The Patoka River occupies a valley that is broad in its lower reaches (western) in comparison with most valleys in the dissected upland area through which the river flows. The broad valley is underlain by alluvial and lacustrine deposits that are 50 to 80 feet thick in the vicinity of the dam site.

Bedrock formations in the area include several groups of rocks of Mississippian age and one group of Pennsylvanian age. The Pennsylvanian rocks are principally sandstone and shales. Mississippian rocks include approximately equal amounts of sandstones, shales, and limestone, mostly in beds of 10 to 30 feet thick. The rocks dip westward at about 25 feet per mile. A simplified stratigraphic chart of the exposed sedimentary rocks in the Patoka River Basin is attached.

POTENTIAL RESOURCES

Limestone

The limestones that underlie the reservoir area, unless they are being used commercially, cannot be valued as a mineral resource for land value purposes, because of the great extent of available limestone formations within the State.

Crushed limestone, agricultural lime, and riprap are produced by Mulzer Bros. from a quarry in sec. 10, T. 25, R. 2 W. The limestone in this area is about 30 feet thick, and the top of the limestone is at an elevation of about 620 feet. This quarry is the major producer of crushed limestone in the immediate area. The reservoir extent as proposed, at a 550-foot elevation, would about reach this quarry. Minor protective measures would eliminate possible damage to this industry.

Gypsum

There are three major areas in southwestern Indiana where evaporites occur. The maximum accumulations of these evaporites (gypsum and anhydrite) are found in basins in the following counties: One in southwestern Orange County, northern Spencer County, Perry County, and southwestern Crawford County; one in central and western Martin County and eastern Daviess County; and one in northern Green County, southwestern Owen County and southern Clay County.

The evaporites (gypsum and anhydrite) are found in the lower part of the St. Louis limestone, The lower part of the St. Louis limestone ranges in thickness from 100 feet on the east to 250 feet thick on the west at the Indiana-Illinois border and from 170 to 240 feet in thickness in the basins mentioned above. There are six gypsum and/or anhydrite beds described in the lower St. Louis limestone. These range in thickness from 5 to 25 feet and are interbedded with thin limestone layers.

Gypsum is mined near Shoals, Indiana, by the U. S. Gypsum Company and the National Gypsum Company. National Gypsum encountered the gypsum bed which is relatively flat, lying at 500 feet in depth; and U. S. Gypsum at 400 feet. The gypsum bed being mined in both cases ranges from 14 to 17 feet thick and is high-grade gypsum.

The lower St. Louis limestone in the reservoir area is at least 200 feet thick and is estimated to contain about 15 percent evaporites The evaporite unit should be encountered in the reservoir area at a depth of about 400 feet.

The limestone rocks underlying the reservoir area would normally contain large quantities of water. The additional impounded waters of the reservoir might increase the difficulty in mining the gypsum beds below the reservoir area.

Present operations near Shoals and the other major areas of evaporites listed above would most likely be the areas of future gypsum developments. The reservoir area has potential as a gypsum source, but as present operations have reserves for many decades, production from this area cannot be anticipated in the immediate future.

Oil and gas

The Patoka Reservoir will not adversely affect oil or gas production, as there are no producing wells in the reservoir area. The area has been tested and a number of dry holes drilled. In purchasing the land for reservoir purposes, the lack of production and the number of dry holes would indicate that probable future production would be limited. As there is oil production in the surrounding area, land owners would have hopes of future oil royalties and would value their land accordingly. The seriousness of this problem in land purchasing can only be determined in the future when land acquisition takes place.

Oil production for Dubois County in 1961 was 37,247 barrels. This production came from the oil pools south and southwest of the reservoir area.

Coal

The Pennsylvanian age rock is the Raccoon Creek group which is properly divisible into its formal parts, the Staunton, Brazil, and Mansfield formations. In the area of the reservoir the coal beds that mark the boundaries of these formations cannot be identified with reasonable certainty, or are not continuous enough to be useful boundaries. These Pennsylvanian rocks occupy only a minor number of the tops of ridges in the reservoir area and therefore would not be inundated by reservoir waters.

The coal fields of Indiana are on the eastern side of the eastern interior coal basin. This large basin underlies the southwestern fifth of Indiana, part of northwestern Kentucky, and a large part of Illinois. The Indiana coal fields occupy an area approximately 6,500 square miles in extent. The coal-bearing area is broad in its southern extent, with a maximum with a maximum width of approximately 80 miles, and wedges out to the north in the southern part of Benton County; a north-south length of 200 miles. Most of the coal area in Indiana is drained by the Wabash River and its tributaries.

The coal of commercial value in the Indiana coal field is in rocks of Pennsylvanian age. In the area of the reservoir site, Pennsylvanian rocks occupy only the tops of the ridges, as the site area is the eastern extent of the coal basin rocks. In the reservoir site area the coal is thin or absent. No commercial coal mining has been done, and the only mining of coal has been by farmers mining small seams on their property for their own use.

MINERAL PRODUCTION

Mineral production in Dubois County has been declining, mainly due to decreased coal production. Value of mineral production, except oil and natural gas, in 1962 was $66,000. Production consisted mainly of coal, clay, and sand and gravel. It is expected that this total will be lower in 1963 due to further reduction in coal production in the vicinity of Huntingburg. Three underground coal mines operated during 1962, but the strip coal mine of Hasenour & Sternberg did not operate. Fire clay was mined near Huntingburg for use in fire brick, pottery, and stoneware. Fill sand was produced near Potterville. Oil production in 1962 was 37,247 barrels from areas south and southwest of the reservoir site. A total of 97 drill holes were drilled in search of oil and gas in Dubois County in 1962.

Mineral production value in Crawford County in 1960 and 1961 was about $600,000. In 1962 the value of production declined. Hy-Rock Products Co. operated an underground limestone quarry at Marengo. Mulzer Bros. operated the Eckerty Quarry. Actual production in value figures cannot be given, due to confidentiality of the data since there are only two operating companies. The crushed stone produced was used for riprap, ballast, road material, and agricultural purposes.

Minerals produced in Orange County in 1962 were valued at $498,354. Whetstones were manufactured by Hindestan Whetstone Co. from sandstone quarried near Orleans. These deposits of fine-grained sandstone have yielded material for whetstones and other abrasives for 160 years. As early as the 1820's the finished stones were shipped by flatboat to New Orleans via the White, Wabash, Ohio, and Mississippi Rivers, and thence to markets abroad. Limestone quarries and crushing plants were operated at French Lick, Orleans, and Paoli.

CONCLUSIONS

The Patoka Reservoir will not affect current mineral production of the area adversely. Negotiations for land purchase may be affected by the existence of gypsum deposits underlying the reservoir area and by land owners' hopes for future oil and gas discoveries.

STRATIGRAPHIC CHART OF EXPOSED SEDIMENTARY ROCKS, PATOKA RESERVOIR AREA

System	Group	Formation
Pennsylvanian	Raccoon	Staunton Fm.
		Brazil Fm.
		Mansfield Fm.
Mississippian		Menard Ls.
	Unnamed	Waltersburg Ss.
		Vienna Ls.
		Tars Springs Fm.
		Glen Dean Ls.
		Hardinsburg Fm.
	Stephensport	Golconda Ls.
		Big Clifty Fm.
		Beech Creek Ls.
		Elwren Fm.
		Reelsville Ls.
	West Baden	Sample Fm.
		Beaver Bend Ls.
		Bethel Fm.
		Paoli Ls.
	Blue River	Ste. Genevieve Ls.
		St. Louis Ls.

WATER RESOURCES STUDY
LINCOLN RESERVOIR, EMBARRASS RIVER
WABASH RIVER BASIN
ILLINOIS

A Preliminary Study of Potential Needs and Value of Water for Municipal, Industrial, and Water Quality Control Purposes

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region III
Ohio River Basin Project
Evansville Field Station, Indiana

In Cooperation With The

U. S. DEPARTMENT OF THE ARMY
U. S. Army Engineer District - Louisville, Kentucky

January 1964

EXHIBIT F-6

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I. INTRODUCTION

Authority

The District Engineer, Corps of Engineers, Louisville, Kentucky, by letter dated August 20, 1963, requested the U. S. Public Health Service to furnish ". . . information in accordance with the work plan now under negotiation for your studies for the Wabash River Basin Comprehensive Study . . . ." The letter transmitted Area-Capacity data for the proposed Lincoln Reservoir on Embarrass River as well as other pertinent data and further indicated that a higher seasonal pool could be attained if significant advantage could be gained.

Authority to conduct such studies is provided in the Federal Water Pollution Control Act (Public Law 84-660 as amended by Public Law 87-88 in 1961) and in the Memorandum of Agreement dated November 4, 1958, between the Department of the Army and the Department of Health, Education, and Welfare, relative to the Water Supply Act of 1958 (Title III of Public Law 85-500 as amended by Public Law 87-88).

Purpose and Scope

This report provides a preliminary evaluation of municipal and industrial water supply and surface water quality control needs for the years 1976 and 2010 for the Embarrass River Basin, and the need for and value of water storage in the proposed Lincoln Reservoir for regulation of Embarrass River flow to meet these needs.

The Embarrass River Basin lies within the Counties of Champaign, Clark, Coles, Crawford, Cumberland, Douglas, Edgar, Effingham, Jasper, Lawrence

Richland, and Vermilion in the southeastern portion of the central part of Illinois.

Acknowledgments

Completion of this study could not have been achieved without the cooperation and assistance of Federal and State authorities and by local authorities within the basin. Information was furnished from their publications, records, and files.

Acknowledgment is made to the following agencies:

U. S. Geological Survey

U. S. Soil Conservation Service

Wabash Valley Interstate Commission

Illinois Department of Public Health

Illinois Department of Agriculture

Illinois Division of Waterways

Illinois State Water Survey

II. SUMMARY AND CONCLUSIONS

Summary

1. The proposed Lincoln Reservoir site is in the upper reaches of Embarrass River Basin and in the eastern-central portion of the State of Illinois. The proposed dam site is in Cumberland County, approximately nine miles south of the City of Charleston, Illinois.

2. The quantity and water quality of flows in the Embarrass River directly affect the communities and surrounding areas of Charleston, Newton and Lawrenceville, and may affect the City of Mattoon. The above communities are situated on or near the Embarrass River in the Counties of Coles, Cumberland, Jasper, and Lawrence (See Figure I).

3. Charleston and Mattoon are the greatest water consuming communities along the river and also discharge the greatest municipal waste loads into the river. Lawrenceville which is situated about eight miles from the mouth of the Embarrass River is a significant user of water supplied from a well field. The area surrounding Lawrenceville has a number of oil fields and an oil refinery. Information available at this time indicates that the oil industry discharges wastes into the river to the extent that the water quality in the river.

4. Estimates of storage for regulation of streamflow for the purpose of quality control are based upon the assumption that adequate treatment will be provided for all wastes.

Conclusions

1. It is expected that the urban population of the Embarrass River Basin areas including the Cities of Charleston, Lawrenceville, Mattoon, and

Newton will increase from about 48,000 in 1960 to about 96,000 by the year 2010. Of these population totals, the Cities of Charleston and Mattoon which combined had a population of about 31,000 in 1960 are expected to have a population of about 63,000 by the year 2010.

2. It is anticipated that the Communities of Charleston and Mattoon may need an additional water supply for industrial uses ranging from 0.7 to 1.5 mgd (million gallons per day) by the year 1976 and an additional supply ranging from 4.4 to 6.9 mgd for municipal and industrial purposes by the year 2010. This additional need can be supplied most economically from the proposed multi-purpose Lincoln Reservoir.

3. The Community of Newton will need a dependable river flow ranging from 1.2 to 1.5 mgd by the year 1976 and from 2.4 to 2.8 mgd by the year 2010.

4. The additional needs of small communities that are now using water supplies from wells downstream from the proposed Lincoln Reservoir site can be met by increasing the well field yield. The Lawrenceville area will need an additional 0.2 to 0.8 mgd in maximum dependable yield by the year 2010. This additional yield seems to be within the capacity of the ground water aquifer.

5. Water for quality control could be released from the proposed Lincoln Reservoir in an amount equivalent to an annual draft on storage which could be provided by an impounding reservoir of 5,400 acre-feet. This release could maintain a minimum flow of 21 cfs (cubic feet per second) which is believed reasonable because minimum releases will be held constant for a prolonged period of time. Consequently, the communities downstream will be deprived of the periodic small rises which would normally be available to the downstream users.

6. Approximately 20 acre-feet of annual draft on storage would be required to give a dependable river flow adequate for water supply needs at Newton of about 2.8 mgd. Newton's water supply needs could be taken from the release of 21 cfs leaving sufficient water downstream to assimilate Newton's adequately treated wastes.

7. A more detailed study is necessary to determine needs and assess benefits of storage for streamflow regulation for water quality control in the Lawrenceville area.

8. The proposed Lincoln Reservoir will afford benefits having a minimum value at least equal to the cost of building two single-purpose reservoirs for water supply for Charleston and Mattoon of 3,500 acre-feet and 1,700 acre-feet, respectively. It would also provide benefits for water quality control with a value equivalent to the cost of constructing a single-purpose reservoir having a capacity of 5,400 acre-feet upstream from Charleston. The value of these estimated benefits from water supply would be $1,300,000 for Charleston and $550,000 for Mattoon or about $79,000 and $10,000, respectively, per year. The value of benefit from water quality would be $1,600,000 or about $80,000 annually. The total benefit would be about $3,450,000 in terms of 1963 dollars or about $169,000 per year.

III. DESCRIPTION OF PROJECT

Location

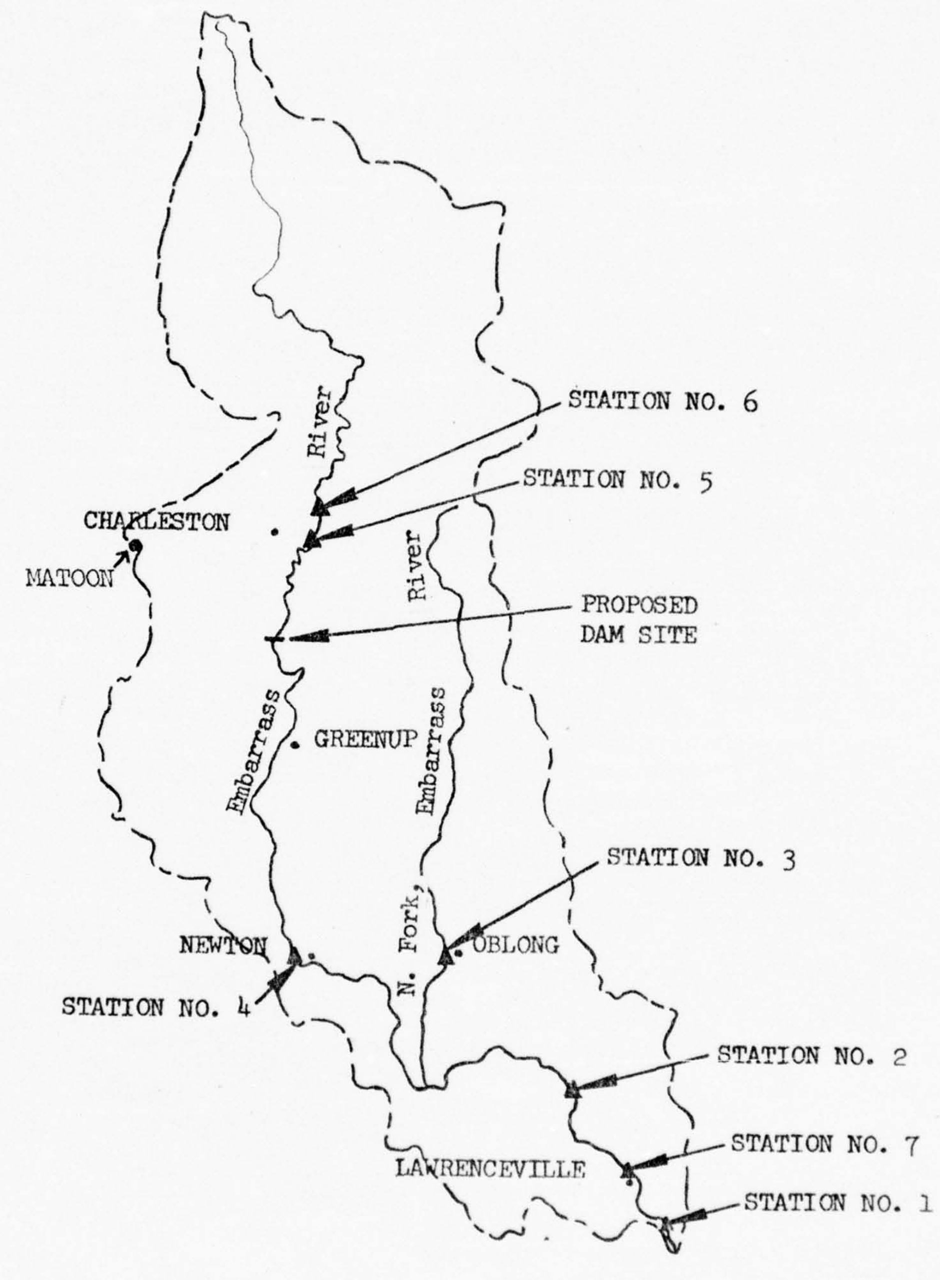
The reservoir site presently under study by the Corps of Engineers is in Cumberland, Coles and Douglas Counties, Illinois, in the upper reaches of the Embarrass River Basin. The proposed dam site is approximately 103 miles above the mouth of the river and about a third of a mile south of the Coles-Cumberland County Line (See Figure I).

Streamflow

The average discharge[1] of the Embarrass River at St. Marie based upon 51 years of record is 1,219 cubic feet per second (cfs) for a 1,513 square mile drainage area. Maximum and minimum mean monthly flows have been about 11,500 cfs and 4.4 cfs, respectively. The minimum daily discharge with a once-in-30-year occurrence is about 1.3 cfs and the minimum daily discharge experienced during 51 years of record was 1 cfs. The minimum 7-day average discharge with a once-in-5-year occurrence interval is about 21 cfs.

Water Quality

Water quality data have been collected by the Illinois Department of Public Health, Division of Sanitary Engineering, at various sampling sites along the Embarrass River (See Figure II). Table 1 gives the results obtained from samples taken at river monitoring stations at crossings of State Roads 16 and 130 over the Embarrass River. These results reflect the quality of water that may be expected to enter the Lincoln Reservoir upstream from Kickapoo Creek.



LINCOLN RESERVOIR REPORT

WATER QUALITY MONITORING STATIONS

DEPARTMENT OF HEALTH, EDUCATION,
AND WELFARE
PUBLIC HEALTH SERVICE
OHIO RIVER BASIN PROJECT
EVANSVILLE, INDIANA FIELD STATION

FIGURE II

Table 1

Water Quality Results*

Embarrass River Basin

Date	Chloride	Sulfate	Alkalinity	Hardness	Spec. Cond.	Dissolved Sol.	Turbidity	BOD (5 day)	pH	Temp.	DO	Coli/100 ml	Enteroc./100 ml	Radioactivity Alpha	Radioactivity Beta	Bacteria/ml	Syndets
Station No. 5 - Hwy. #130 Over Embarrass River 2 mi. S. of Charleston.																	
9-24-58	26	-	288	332	640	380	10	0.7	7.9	--	6.75	2,700	160	--	--	--	--
11-17-59	16	-	136	222	440	270	110	2.8	7.5	34	10.8	60	800	--	--	40,000	0.0
1-17-61	29	66	292	324	660	400	12	1.5	8.2	38	15.0	110	100	Tri.	Tri.	2,300	0.0
9-6-61	11	30	134	220	420	250	35	5.9	8.4	78	9.2	120	2-			6,700	0.0
2-14-62	15	45	174	252	470	280	30	1.0	7.8	40	11.6	260	16	0.8	27	12,000	0.2
2-14-62	14	45	172	252	470	280	30	1.5	8.0	40	11.8	0	4	1.6	41	24,000	0.3
8-21-62	18	18	220	240	480	290	30	13.6	7.8	78	23.7	140	2-	0.4	26	7,000	0.01
5-28-63	8	110	180	228	440	260	80	8.8	8.3	70	9.5	570	24	1.1	9	5,000	0.1
8-27-63	48	130	104	270	570	340	40	1.6	7.6	74	7.2	640	16	1.1	13	2,800	0.0
Station No. 6 - Hwy. #16 Over Embarrass River 4 mi. E. of Charleston.																	
9-24-58	14	-	256	272	560	340	60	3.0	7.8	70	6.7	100	75	--	--	--	--
11-17-59	26	-	136	214	430	260	110	2.4	7.7	34	11.1	80	2400	--	--	44,000	0.0
1-17-61	73	65	296	340	590	350	17	1.5	7.7	38	10.8	30	8	3	Tri.	490	0.0
9-6-61	11	31	204	240	430	260	45	8.0	8.3	80	10.5	210	2			4,500	0.0

*From unpublished data furnished by Illinois Department of Public Health, Division of Sanitary Engineering.

The Cities of Mattoon and Charleston discharge treated wastes into Kickapoo Creek or its tributaries and these communities are expected to provide adequate treatment to their wastes. Even so, the recreational value of the portion of the reservoir extending up Kickapoo Creek may be decreased because of an aesthetic barrier involved.

Pertinent Data

For study purposes a minimum pool tentatively selected by the Corps of Engineers would provide 61,315 acre-feet and a seasonal pool would store a total of 126,765 acre-feet of water. These storage volumes would be achieved at elevations 584 feet and 596 feet for minimum and seasonal pools, respectively.

IV. DESCRIPTION OF STUDY AREA

Location and Boundaries

The Embarrass River Basin is located in the southeastern portion of the central part of Illinois and lies generally in a north and south direction with the lower portion of the basin lying in a northwesterly and southeasterly direction (See Figure I). The Embarrass River, which rises near the city limits of Urbana, drains an area of 2,438 square miles in parts of twelve counties: Champaign, Clark, Coles, Crawford, Cumberland, Douglas, Edgar, Effingham, Jasper, Lawrence, Richland, and Vermilion. The main stem of the Embarrass is approximately 130 miles long and discharges into the Wabash River about 6 miles downstream from Vincennes, Indiana. The basin is comparatively long and narrow. The two principal tributaries tend to broaden the basin somewhat but because they each follow a course generally parallel to the main stem the effect is minimized.

Muddy Creek with a drainage area of 213 square miles has its source about 8 miles southwest of Charleston and enters the Embarrass River about 6 miles southwest of Greenup.

North Fork Embarrass River drains an area of 361 square miles. It flows from a point near Kansas, Illinois, in a southerly direction and enters the Embarrass River about 10 miles south and somewhat west of Oblong.

Geography

Originating in the rolling ridges of southern Champaign County, the Embarrass River flows out onto the nearly level prairies of northern Douglas

County. Here the Embarrass River flows as a sluggish prairie stream meandering across the level uplands. In this area many channelized tributaries form the outlets for the numerous drainage districts which maintain surface ditches and tile lines to remove the excess water from several hundred thousand acres of highly productive farmland. Near the Coles-Douglas County Line the river drops abruptly into a gorge and follows this steep-walled, v-shaped valley southward to about Charleston, Illinois. For about 45 miles the Embarrass River flows at the bottom of a steep-walled gorge 50 to 70 feet below the adjacent upland. Near the Coles-Cumberland County Line, the river flowing in a preglacial channel, occupies a broad flat-bottomed valley with steep valley walls rising sharply to the upland. Throughout its course, the Embarrass River occupies a sharply defined valley.

Climate

Temperature in the basin, based upon 30 years of record during the period 1931 through 1960, ranges from a mean annual temperature of 52.7 degrees at Urbana, 53.6 degrees at Charleston, and 56.2 degrees at Vincennes, Indiana. For the same period of record, the mean monthly low was about 28 degrees for the month of January and the mean monthly high was about 78 degrees for the month of July.

Precipitation in the basin is as follows: mean annual precipitation for Urbana is 37 inches, for Charleston 38.6 inches, and for Vincennes 36.7 inches. The mean annual precipitation for the entire Embarrass Basin is approximately 38 inches.

Principal Communities and Industries

The principal communities located in the Embarrass River Basin are: Casey, Charleston, Lawrenceville, Mattoon, Newton, and Tuscola. The City of Mattoon is on the watershed boundary with sections of the community draining into the Little Wabash River; however, the city's treated sewage is discharged into Kickapoo Creek, a tributary to the Embarrass River.

Charleston and Mattoon have machinery manufacturing plants. An oil refinery is located at Lawrenceville, and Newton has a uniform manufacturing plant. Each community serves as a commercial center for the surrounding agricultural area but the basin has not experienced significant industrial growth.

V. ECONOMY

Present Economy

Area Included

The area of influence of the proposed Lincoln Reservoir Project covers 2,164 square miles and five counties in southeastern Illinois, i.e., Coles, Cumberland, Jasper, Crawford, and Lawrence.

Agriculture

Farming occupies a relatively prominent role in the economy of the study area. In manpower the agricultural industry engaged 6,334 workers and accounted for 16.1 percent of the labor force in 1960.

Even though the number of farms has declined since 1939, the harvested acreage has increased by 12 percent and the value of farm products sold has nearly doubled.

Agricultural Trends in the
Five-County Area
1939-1959

	Farms	Acres Harvested	Farm Products Sold*
1939	9,857	640,409	$ 26,339,943
1959	6,365	797,937	$ 50,345,923

* Expressed in constant 1959 dollars

Mineral Industries

The mineral wealth in the basin consists of petroleum, stone, sand, and gravel (See Table 2). Lawrence County produced 7,569,000 barrels of crude petroleum in 1960 representing 10 percent of the state total output. The annual value of mineral output approximates $29,000,000 for the study area. This amount represents about 5 percent of the total mineral activities for the state of Illinois. Employment data for the mineral activities hardly changed from 1950 to 1960. There were 1,222 employed representing 3 percent of the state total mineral industries employment in 1960.

Table 2

Summary of Mineral Production in Study Area *

Location	Minerals	Value
Coles County (1960)	Stone, sand, gravel	$ 790,000
Crawford (1960)	Sand, gravel	136,000
Cumberland (1959)	Sand, gravel	125,000
Lawrence (1960)	Sand, gravel	238,000
	Sub Total	$ 1,289,000
Coles County (1958)	Crude petroleum, natural gas	$ 1,424,000
Crawford (1958)	Crude petroleum, natural gas	9,251,000
Cumberland (1958)	Crude petroleum, natural gas	2,075,000
Lawrence (1958)	Crude petroleum, natural gas	15,036,000
	Sub Total	$27,786,000
	Grand Total	$29,075,000

* Sources: Minerals Year Book 1961, Volume III, Area Reports
Census of Mineral Industries 1958, Volume II, Area Statistics

Manufacturing

Manufacturing employed 7,336 workers, representing 18.6 percent of the labor force in 1960. In contrast, manufacturing employment in 1950 was 15 percent with 6,118 workers. Between 1954 and 1958 value added by manufacture * advanced nearly 50 percent, growing from $43,097,000 in 1954 to $63,937,000 by 1958. **

The manufacturing base of the study area is diversified in character. Table 3 lists manufacturing plants by major industrial category with ranges of employment. Of the 129 plants operating in 1958, 65 percent had fewer than 20 employees. Only .7 percent registered more than 250 employees. Ohio Oil Company in Robinson with 633 employees in 1960 had the largest employment force. In terms of plant establishments, the ranking industries are food processing and printing and publishing. However, in terms of overall measured employment according to 1960 data, the leading industry was the electrical machinery industry with 890 employees, followed closely by the non-electrical machinery industry totaling 778 employees, while food processing accounted for 616 workers.

Table 4 summarizes the manufacturing plant information in each county and indicates the possible high water intake plants and potential waste producers. All plants are included which had over 100 employees and whose 4-digit Standard Industrial Classification code industry is included in the

* Data on value added by manufacture for Lawrence County were not disclosed for either 1954 or 1958.

** Expressed in constant 1958 dollars

Table 3

Number and Employment Size of Manufacturing Plants
Study Area
1958

	EMPLOYEES				
Type	(1-19)	(20-99)	(100-249)	(250-over)	Total
Food & Kindred Products	15	7		1	23
Tobacco Products					
Textile Mill Products					
Apparel & Related Products	5	1	3		9
Lumber & Wood Products	9	3	1		13
Furniture & Fixtures	1	1		1	3
Paper & Allied Products	5				5
Printing & Publishing	16	2			18
Chemical & Allied Products	3				3
Petroleum & Coal Products	3	1	1	1	6
Rubber & Plastic Products					
Leather & Leather Products	1	2	1	3	7
Stone, Clay, Glass Products	9			1	10
Primary Metals		2			2
Fabricated Metals	2	2			4
Non-Electric Machinery	5	4	1	1	11
Electric Machinery		1		1	2
Transportation Equipment	1				1
Instruments & Related Products	2				2
Miscellaneous	7	3			10
Total	84	29	7	9	129

Table 4

Summary of Manufacturing Plants by Counties, 1958*

COLES COUNTY

58 Plants
7 with over 100 Employees
High Water Intake Plants

SIC** Code	Industry Description	Number Plants	Employment Range	National Average Water Intake per Employee per Year Gallons
3569	Gen. Industry Machinery	1	100-249	145,000
3531	Construction Machinery	1	250-499	105,000
3641	Electric Lamps	1	250-499	106,000

Potential Waste Producers

2011	Meat Packing	2	1-19	
2011	Meat Packing	1	20-49	
2022	Natural Cheese	1	1-19	

CUMBERLAND COUNTY

12 Plants
2 over 100 Employees
No High Water Intake Plants

CRAWFORD COUNTY

26 Plants
4 over 100 Employees
High Water Intake Plants

2071	Confectionery Products	1	250-499	666,000
2911	Petroleum Refining	1	500-999	9,727,000
3261	Vitreous Plumb. Fixtures	1	250-499	229,000
3271, 2, 3	Ready Mix Concrete	3	1-19	1,386,000

Potential Waste Producers

2015	Poultry Dress. Plants	1	1-19	
2024	Ice Cream & Freez. Deserts	1	1-19	

JASPER COUNTY

14 Plants
2 over 100 Employees
No High Water Intake Plants

LAWRENCE COUNTY

19 Plants
1 over 100 Employees
High Water Intake Plants

2911	Petroleum Refining	1	500-999	9,727,000
2952	Asphalt Felt & Coatings	1	50-99	1,406,000
3271-2	Concrete Mix	2	1-19	1,386,000

Potential Waste Producers

2011	Meat Packing Plants	1	1-19	
2015	Poultry Dress. Plants	1	1-19	

* 1958 Census of Manufactures

** Standard Industrial Classification

listing of industries with an intake of over 20 million gallons per year in the Industrial Water Use Survey, 1958 Census of Manufactures. Plants with fewer than 100 employees are listed only if the industrial water intake per employee for their SIC categories is very high as shown in the Table.

Transportation

Since the Embarrass River is not commercially navigable at the present time, no river transportation is found in the basin. The area is serviced by only one airline, the Ozark, which provides short hauls to cities having multiple-line service. Four railways (New York Central, Nickel Plate Road, Illinois Central, and the Baltimore & Ohio) accommodate passenger travel and carry freight loads to all major commercial centers. Unhampered accessibility to all areas within the basin results from two highways (U.S. 45 and State Route 1) crossing the basin in the north-south direction and four highways (U.S. 40, U.S. 50, and State Route 16) running east-west. Interstate Highway 70 will cross the basin when completed. Intrastate as well as interstate trucking facilities insure the rapid transport of both import and export goods.

Income

The per capita cash income in the study area in 1959 was $1,595 as compared to the state per capita cash income of $2,181, and $1,849 for the Nation. Average median family income in the study area had risen from $2,594 in 1950 to $4,513 in 1960, an increase of 74 percent. During the same period the state median family income increased from $3,627 to $6,566, an increase of 81 percent. These figures indicate

that the study area is behind the state both in value of income and rate of increase. However, because of the rural nature of the study area and possibility of income in the form of farm products, the real income may compare somewhat more favorably with the state average than is indicated.

Population

The population in the five counties has remained stable during the thirty-year period 1930-1960. Population in 1960 numbered 103,433 which is nearly unchanged from the population mark of 103,513 recorded in 1930. The area's population comprised 1.02 percent of Illinois' population in 1960. Urban population stood at 45,212 in 1960 and composed 44 percent of all population, while rural-farm and rural non-farm population totaled 58,221 and represented 56 percent of the area's population. The five-county area is considerably less urbanized than either the state of Illinois or the Nation. Illinois was 80 percent urbanized and the United States was 70 percent urbanized in 1960.

There are only five cities in the area: Charleston, Mattoon, Robinson, Lawrenceville, and Newton. The largest is Mattoon whose population in 1960 was 19,088.

Projected Economy

Projections of the economy of the Lincoln Reservoir Project area of influence were derived from determining historical trend relationships between the study area and the state, and projecting those relationships using as the basis projections for the state prepared by the National Planning Association, Washington, D. C. Past trends were modified in accordance with judgment based on additional information. These projections may be modified, if necessary, upon receipt of the Arthur D.

Little Company, Inc. report of the Economic Base Study of the Ohio River Basin.

Employment Projections

Projected employment is given in Table 5. Agriculture and mining will continue to undergo downturns in employment as technical advances increase productivity. The non-commodity industries * are expected to continue to gain greater shares of the labor force. Manufacturing is projected to share a lesser percentage of the labor force in 1976--18.3 percent-- compared to its percentage share of 18.6 in 1960. The manufacture of electrical machinery will probably continue to lead in employment and non-electrical machine production will be next in importance.

Population Projections

Population, as related to expected patterns in state and national growth, is projected to vary from its stable path of the past and to reach 125,000 by 1976, and an estimated level of 180,000 in the year 2010 (See Table 6 and Figure III). Separate projections for townships and inclusive urban centers reveal an upward and moderate picture of population growth.

* Transportation-Communication-Utilities, Trade, Finance, Services, and Government

Table 5

Historical and Projected Employment
Study Area

	1950	% of CE[a]	1960	% of CE[a]	1976	% of CE[a]
Total Civilian Employment	40,809	100.0	39,328	100.0	48,680	100.0
Agriculture	9,356	22.9	6,334	16.1	4,020	8.3
Mining	1,244	3.1	1,222	3.1	850	1.7
Construction	2,619	6.4	2,316	5.9	3,700	7.6
Transportation-Com.-Utilities	3,928	9.6	3,215	8.2	3,800	7.8
Trade	7,457	18.3	7,964	20.3	10,300	21.2
Finance	827	2.0	1,045	2.7	1,500	3.1
Services	6,378	15.6	5,903	15.0	10,000	20.5
Government	2,882	7.1	4,003	10.1	5,600	11.5
Manufacturing	6,118	15.0	7,336	18.6	8,910	18.3
Furniture-Wood-Lumber	838	2.1	616	1.5	600	1.2
Primary Metals	101	.2	117	.3	120	.2
Fabricated Metals	303	.7	165	.4	220	.5
Non-Electric Machinery	254	.6	778	2.0	1,000	2.1
Electric Machinery	259	.6	890	2.2	1,800	3.7
Transportation Equipment	42	.1	30	.1	50	.1
Other Durables	727	1.8	651	1.6	750	1.5
Food	621	1.5	591	1.5	600	1.2
Textiles	71	.2	78	.2	10	-----
Apparels	377	.9	580	1.5	400	.8
Printing	287	.7	339	.9	460	.9
Chemicals	92	.2	459	1.2	600	1.2
Other Non-Durables	2,146	5.3	2,042	5.2	2,300	4.7

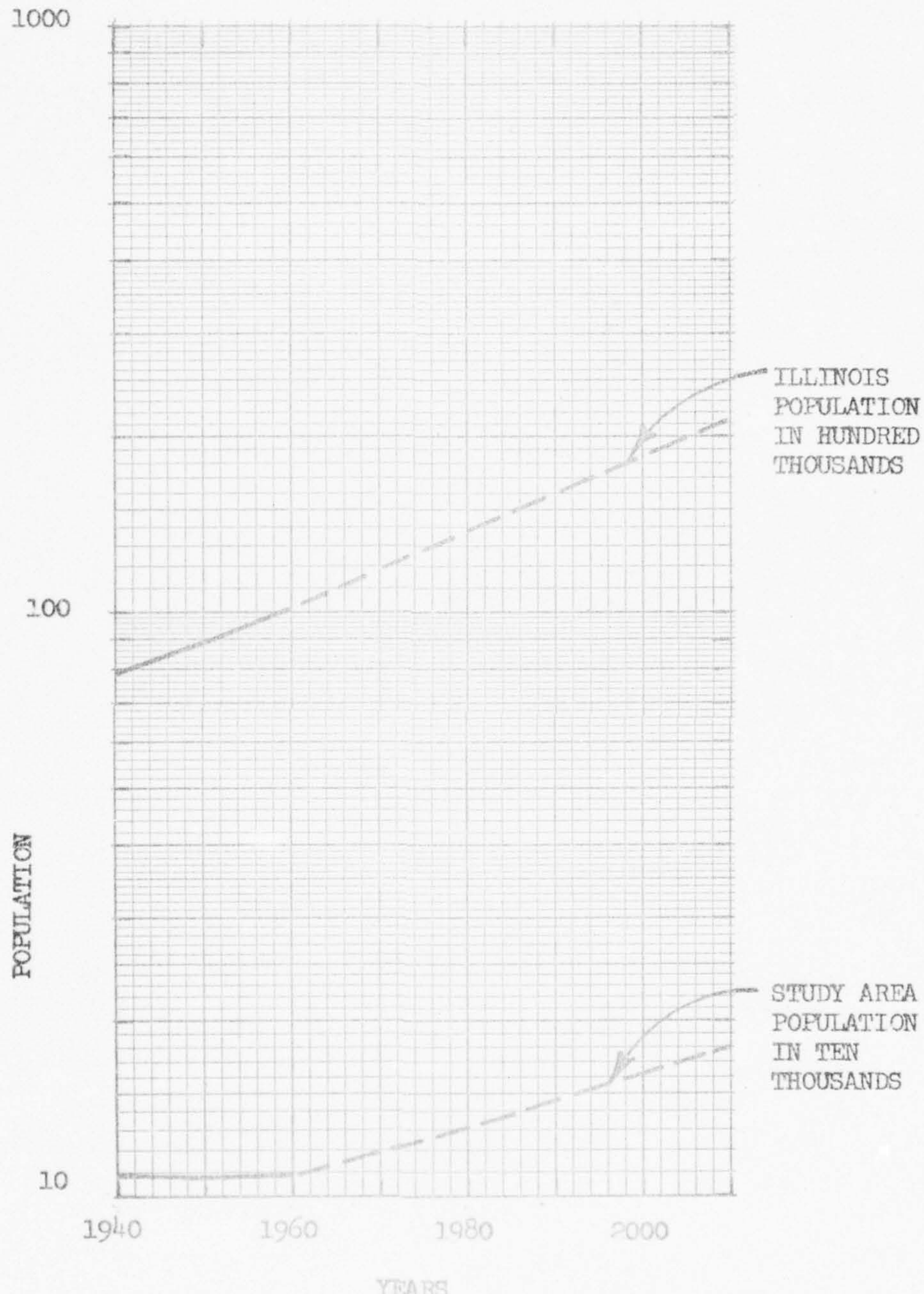
[a] Civilian Employment

Table 6

Historical and Projected Population
Study Area

	1950	1960	1976	2010
State of Illinois	8.7 Mil.	10.1 Mil.	13.0 Mil.	21.0 Mil.
Study Area (Coles, Crawford, Cumberland, Jasper, Lawrence Counties)	104,766	103,433	125,000	180,000
Coles County				
Charleston Township (Incl. Charleston)	10,713	11,924	20,000	28,000
Charleston Only	9,164	10,505	18,000	25,000
Mattoon Township (Incl. Mattoon)	17,906	19,138	26,000	35,000
Mattoon Only	17,547	19,088	24,000	31,000
Crawford County				
Robinson Township (Incl. Robinson)	8,130	9,056	12,500	20,000
Robinson Only	6,407	7,226	9,500	16,000
Jasper County				
Wade Township (Incl. Newton)	4,270	4,269	6,500	9,500
Newton Only	2,780	2,901	4,500	7,200
Lawrence County				
Lawrenceville Area* (Incl. Lawrenceville)	13,103	12,288	15,000	24,000
Lawrenceville Only	6,328	5,492	7,000	10,000

* This area includes Lawrenceville, Bridgeport, and Christy Townships.



LINCOLN RESERVOIR REPORT

POPULATION PROJECTIONS

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

OHIO RIVER BASIN PROJECT
EVANSVILLE, INDIANA FIELD STATION

FIGURE III

VI. WATER REQUIREMENTS

As the population increases and industrial growth occurs, greater demands will be made for water. Hence, the growth projected in the preceding section supports projections of seasonal water needs. Water uses by certain industries are shown in Table 2.

Past and Present Water Use

Municipal

Water use by the municipalities in the basin or within its influence is given in Table 7.[2]

Industrial

The major portion of industrial needs for water in the Embarrass River Basin are served from the municipal supplies.

Existing Sources

Ground Water

Wells are presently the chief source of water supply for most of the communities in the Embarrass River Basin. The larger communities utilizing well fields for their municipal water supply are: Arcola, Casey, Greenup, Lawrenceville, Martinsville, Mattoon, Toledo, Tolono, Tuscola, and Villa Grove. The Community of Sumner receives its water supply from Bridgeport which in turn purchases its supply from Lawrenceville.

Ground water in the basin is not exhausted even though it is utilized to a much broader extent than surface water. Most of the ground water is

Table 7

Municipal Water Systems

Embarrass River Basin

Municipality	Pop. 1960	1963 Est. Pop. Served	Source	Rated Plant Capacity (MGD)	Average Plant Output (MGD)	Treatment
Arcola	2,273	2,200	Wells	0.20	0.13	Filtration, Softening, Chlorination
Ashmore	447	447	Well	0.07	0.07	Filtration and Contact Beds
Bridgeport	2,260	2,230	(Obtains water supply from Lawrenceville.)		0.21	
Broadlands	344	322	Well	0.06	0.02	Iron Removal, Filtration, Fluoridation
Camargo	276	--	Well	--	0.005	None
Casey	2,893	2,975	Wells	0.44	0.20	Softening, Filtration, Chlorination
Charleston	10,505	11,500	Lake Charleston	2.00	1.0	Filtration, Taste and Odor Control, Fluoridation, and Chlorination
Flat Rock	497	515	Wells	0.24	0.01	None
Greenup	1,477	1,500	Wells	0.29	0.08	Fluoridation
Hindsboro	376	300	Wells	0.19	0.02	Filtration, Chlorination, Fluoridation
Hume	449	--	Well	0.12	0.01	Iron Removal, Filtration, Chlorination, Fluoridation

Table 7 (Cont'd)

Municipal Water Systems

Embarrass River Basin

Municipality	Pop. 1960	1963 Est. Pop. Served	Source	Rated Plant Capacity (MGD)	Average Plant Output (MGD)	Treatment
Kansas	815	810	Wells	0.12	0.04	Softening, Iron Removal, Filtration, Corrosion Correction
Lawrenceville	5,492	8,984	Wells	1.57	1.37	Chlorination, Filtration, Fluoridation
Long View	270	--	Well	0.07	0.01	Chlorination, Fluoridation
Martinsville	1,351	850	Wells	0.12	0.08	Iron Removal, Softening, Filtration, Chlorination
Mattoon	19,088	24,993	Little Wabash River Imp. & Wells	4.50	1.50	Softening, Iron Removal, Filtration, Fluroidation, Chlorination
Metcalf	278	200	Well	0.012	0.005	Chlorination, Corrosion Control
Newman	1,097	1,000	Drift Well	0.18	0.05	Softening, Iron Removal, Filtration, Chlorination, Fluoridation
Newton	2,901	4,400	Embarrass River	0.40	0.25	Filtration, Chlorination, Fluoridation
Oakland	939	980	Tributary of Embarrass River (Imp.)	0.24	0.06	Softening, Iron Removal, Filtration, Chlorination

Table 7 (Cont'd)

Municipal Water Systems

Embarrass River Basin

Municipality	Pop. 1960	1963 Est. Pop. Served	Source	Rated Plant Capacity (MGD)	Average Plant Output (MGD)	Treatment
Oblong	1,817	2,200	(Obtains water supply from Robinson)	0.22	0.14	
Pesotum	460	375	Well	0.12	0.02	Iron Removal, Chlorination, Filtration
Philo	740	800	Drift Wells	0.12	0.03	Iron Removal, Filtration, Fluoridation
St. Marie	347	350	Drift Well	0.015	0.012	Iron Removal, Filtration, Fluoridation
Stoy	185	--	(Obtains water supply from Robinson)			
Sumner	1,035	995	(Obtains water supply from Lawrenceville)		0.06	
Toledo	998	975	Drift Wells	0.18	0.05	Softening, Iron Removal, Filtration, Chlorination, Fluoridation
Tolono	1,539	1,570	Drift Wells	0.29	0.10	Softening, Iron Removal, Filtration, Fluoridation
Tuscola	3,875	4,000	Rock Wells	0.30	0.25	Softening, Iron Removal, Filtration, Chlorination, Fluoridation

Table 7 (Cont'd)

Municipal Water Systems

Embarrass River Basin

Municipality	Pop. 1960	1963 Est. Pop. Served	Source	Rated Plant Capacity (MGD)	Average Plant Output (MGD)	Treatment
Villa Grove	2,308	2,200	Rock Wells	0.40	0.13	Softening, Iron Removal, Filtration, Chlorination, Fluoridation
Westfield	636	615	Rock and Drift Wells	0.07	0.015	Iron Removal, Chlorination, Fluoridation

obtained from deposits of sand and gravel in the glacial drift, and a few of the public supplies are obtained from bedrock aquifers. Wells tapping the sand and gravel aquifers have yields ranging from 20 to more than 500 gpm (gallons per minute) while the sandstone aquifers yield less than 20 gpm and the limestone aquifers yield as much as 500 gpm.[3]

Prior to the glacial age, this part of the State had a heavily eroded landscape of deep valleys and high hills. During the glacier period many of these valleys were filled with glacial sand and gravel, and at these locations of unconsolidated material the possibility of obtaining significant supplies of ground water exist. Additional testing of sub-surface conditions must be made before knowledge of underground reserves of water is sufficient.[4]

Laboratory analyses have been performed on samples from pumping municipal wells of several communities throughout the basin. The results of these laboratory tests are listed in Table 8.

Surface Water

Mattoon has two impoundments on tributaries of the Little Wabash River. The first reservoir was constructed in 1937 with a surface area of 144 acres and the second in 1957 with a surface area of 1,270 acres. Combined they provide a safe yield of 9.0 mgd. These reservoirs are the chief source for Mattoon's water supply. Wells serve as a standby reserve.

Charleston's entire water needs are supplied from Lake Charleston, an impoundment of the Embarrass River. This reservoir was built in 1947 with a surface area of 337 acres and an original capacity of 693.6 million gallons. A survey made in 1960 by the staff of the Illinois Water Survey found that the reservoir had suffered a 40 percent loss in original volume due to siltation. The safe yield for Charleston has not been furnished.

Table 8

Quality of Municipal Water Supplies[3]

Ground Water

Embarrass River Basin

Municipality	Date	Iron (total)	Manganese	Calcium	Magnesium	Ammonium	Sodium	Silica	Fluoride	Boron	Chloride	Nitrate	Sulfate	Alkalinity (As Ca CO_3)	Hardness (As Ca CO_3)	Turbidity	Color	Odor *	Temp.
Arcola	6-48	6.0	0.3	67.6	29.3	15.1	112.5	26.3	0.2	-	51.0	0.2	0.6	504	290	50	25	0	55.5°F
"	12-55	4.1	-	-	-	-	-	-	0.2	-	21	4.8	-	356	232	24	0	0	55 °F
Casey	4-59	5.1	0.0	38.4	18.7	16.4	277	11.8	0.5	0.1	227	0.3	0.6	500	173	21	0	0	56 °F
"	4-59	2.3	0.1	65.2	29.7	5.3	83	15.6	0.5	0.1	48	0.1	1.4	412	285	12	0	0	55 °F
Greenup	6-48	0.3	0.2	75.1	29.6	Tr.	2.8	21.1	0.1	-	5.0	6.8	60.7	240	310	Tr.	0	0	54.2°F
"	4-59	0.4	0.1	68.1	28.8	Tr.	11	14.9	0.1	0.2	5.0	9.3	60.1	236	289	2	0	0	54 °F
Kansas	6-48	3.1	Tr.	93.1	34.9	8.1	21.4	28.0	0.1	-	6.0	Tr.	8.6	428	377	40	0	0	55 °F
Lawrenceville	4-48	0.3	Tr.	61.3	11.6	Tr.	0.9	16.1	0.1	-	7.0	11.6	26.5	156	201	0	0	0	56 °F
Martinsville	6-48	1.7	0.0	73.3	33.1	4.3	68.3	17.9	0.5	-	78.0	0.4	1.4	368	320	Tr.	0	Tr.	57.5°F
Mattoon	6-48	3.8	Tr.	93.6	37.0	5.9	2.3	21.8	0.2	-	4.0	1.6	58.2	340	386	40	0	0	55.6°F
Newman	6-53	1.1	0.1	69.4	26.2	1.3	33	22	0.5	-	5	0.0	1.8	348	281	1	0	0	54.4°F
Toledo	6-48	2.0	0.2	57.2	21.1	0.4	36.3	23.8	0.3	-	16.0	1.1	32.7	252	230	25	0	Tr.	52.5°F
"	4-59	1.3	0.1	52.5	21.8	Tr.	44	14.3	0.5	0.1	24	3.7	26.7	252	221	5	0	0	54 °F
Tolono	12-48	5.2	0.0	109.6	38.9	13.3	113.2	29.8	0.4	-	8.0	0.5	1.0	704	434	28	0	Tr.	54 °F
Villa Grove	6-48	0.1	0.0	51.7	24.5	0.5	115.9	14.7	0.2	-	79	0.1	11.5	360	230	0	0	H_2S	63.5°F
" "	6-60	0.1	0.0	51.4	25.9	0.5	118	10.4	0.4	0.1	83	0.9	11.9	364	235	0	0	0	64 °F

*Code
0 = None
Tr = Trace
H_2S = Hydrogen Sulphide

The only other community in the basin presently utilizing the Embarrass River as its source of water supply is Newton. For a period prior to December 1924, Lawrenceville obtained its water from the Embarrass. This source was abandoned because of the salt water from oil wells in the drainage area.[5]

Oakland has an impoundment on a tributary to the Embarrass River known locally as Lake Oakland. This reservoir has an impounded safe yield of 0.12 mgd.

Oblond and Robinson are presently purchasing their water supplies from the Community of Palestine, Illinois, located on the Wabash River.

Ranges in the quality of surface water in the Embarrass River are given in Table 9.[6]

Additional Water Needs

Municipal

Water demands for communities will vary with the economy of the area and with the availability of water of acceptable quality. Table 10 shows the estimated future per capita and municipal use for the major communities located in the basin. This tabulation gives the best estimate of future municipal water requirements that can be made at this time. If more detailed and more reliable data become available, a revision of estimates for future municipal use may become necessary. Light industrial uses are expected to be served from the municipal supply. Table 10 includes such anticipated use.

Table 9

Water Quality Results

Embarrass River Basin

(Downstream From Proposed Reservoir)

Date	Chloride	Sulfate	Alkalinity	Hardness	Spec. Cond.	Dissolved Sol.	Turbidity	BOD (5 day)	pH	Temp.	DO	Coli/100 ml	Enteroc./100 ml	Radio-activity Alpha	Radio-activity Beta	Bacteria/ml	Syndets
Station No. 1 - Two miles east of Billet on Rural Road																	
6-24-58	270	49.0	208	195	480	290	70	0.2	8.2	70	5.6	28,000	250	2.8	42.3	-	-
6-3-59	36	-	110	124	350	210	330	3.8	8.0	68	5.2	12,000	700	9	120	-	0.0
7-28-59	145	-	142	192	720	470	65	4.7	7.7	80	1.8	25,000	130	Tr.	34	120,000	-
11-17-59	92	-	76	120	530	320	440	6.9	7.3	36	8.8	9,000	14,000	29	Tr.	190,000	0.0
1-16-61	400	85	188	270	1780	1150	30	4.4	7.7	38	9.3	100	2	Tr.	0.0	5,400	0.0
9-5-61	96	27	260	265	710	430	50	7.7	8.2	80	7.8	570	10	2	0	440,000	0.0
2-14-62	40	39	142	208	480	290	80	1.7	7.6	40	11.1	130	-2/10 ml	2.5	105	330,000	0.2
8-21-62	39	23	212	220	540	320	55	4.0	7.7	80	5.0	88,000	800	2.0	26	100,000	0.0
5-28-63	50	38	192	244	670	400	90	8.2	8.4	70	9.0	23,000	50	1.9	11	100,000	0.2
8-27-63	42	293	136	330	820	490	180	8.6	8.1	74	5.8	16,000	110	2.3	71	21,000	0.3
Station No. 2 - Seven miles north and four miles west of Lawrenceville on Rural Road																	
7-28-59	39	-	188	204	510	310	100	1.1	8.2	78	6.5	10	14	4.0	Tr.	620	-
11-17-59	59	-	86	98	400	240	420	5.6	7.3	36	9.9	13,000	45,000	13	29	170,000	0.0
1-17-61	340	58	232	280	1580	1110	20	2.2	7.9	34	12.4	120	52	3	Tr.	940	0.5
9-6-61	92	25	252	264	610	370	60	3.7	8.1	78	7.8	400	18			6,200	0.0
2-14-62	33	40	154	224	480	290	70	1.6	7.6	40	11.8	260	6	5.4	59	5,800	0.2
8-21-62	22	14	208	234	489	290	60	3.2	7.8	80	6.3	410	26	2.1	37	6,200	0.0
5-28-63	57	38	176	216	770	460	170		8.2	70	8.2	14,000	130	3.6	16	4,000	0.0
8-27-63	12	115	92	156	380	230	200	1.9	8.1	74	6.7	1,200	26	2.9	57	19,000	0.0

Table 9 (Cont'd)

Water Quality Results

Embarrass River Basin

(Downstream From Proposed Reservoir)

Date	Chloride	Sulfate	Alkalinity	Hardness	Spec. Cond.	Dissolved Sol.	Turbidity	BOD (5 day)	pH	Temp.	DO	Coli/100 ml	Enteroc./100 ml	Radio-activity Alpha	Radio-activity Beta	Bacteria/ml	Syndets
Station No. 3 - Hwy. No. 33, 2 miles west of Oblong on North Fork Embarrass River																	
9-24-58	124	-	206	212	760	460	30	0.9	7.7	68	6.8	300	100	-	-	-	-
7-28-59	118	-	140	136	630	380	80	2.1	7.8	74	7.2	10	4	Tr.	38	670	-
11-17-59	270	-	88	152	1080	650	180	4.9	7.3	36	10.2	100	7,000	Tr.	55	53,000	0.0
1-17-61	285	40	128	144	1160	810	45	2.0	7.6	36	10.7	200	4,800	Tr.	Tr.	17,000	0.0
9-6-61	288	25	270	210	1160	700	25	4.4	7.8	76	6.3	36,000	36	-	-	2,600	0.0
2-14-62	111	55	138	230	710	430	30	1.7	7.6	40	11.0	100	12	3.3	94	6,300	0.4
8-21-62	188	10	220	580	970	580	70	3.0	7.6	78	5.4	230	58	1.0	42	40,000	0.0
5-28-63	102	23	204	240	1070	640	45	3.4	0.8	70	7.3	9,000	110	1.2	16	5,000	0.0
8-27-63	56	419	120	620	1220	730	60	6.2	7.7	74	7.7	750	20	0.8	28	8,000	0.3
Station No. 4 - Hwy. No. 130 at Newton																	
9-24-58	14	-	288	246	490	290	40	2.4	7.9	70	7.8	70	50	-	-	-	-
7-28-59	24	-	204	220	410	280	200	2.8	8.2	76	6.4	40	150	4.1	47	5,300	-
11-17-59	24	-	134	174	410	250	240	4.3	7.5	34	13.2	300	9,000	12	34	60,000	0.0
1-16-61	31	50	236	268	600	360	10	1.2	8.3	34	14.0	140	50	Tr.	Tr.	3,300	0.0
9-6-61	32	20	276	284	570	340	45	3.4	8.0	78	6.9	37,000	60	Tr.	Tr.	23,000	0.0
2-14-62	15	48	180	264	490	300	40	2.4	7.7	40	11.6	700	10	3.4	49	19,000	0.2
8-21-62	19	13	192	220	460	280	30	4.8	7.8	50	7.0	76,000	160	1.0	25	15,000	0.01
5-28-63	11	43	196	240	540	320	80	10.8	8.4	70	11.5	8,000	76	1.6	11	11,000	0.2
8-27-63	18	95	112	232	450	270	120	1.8	2.9	74	6.7	23,000	96	1.6	50	12,000	0.1

Table 9 (Cont'd)

Water Quality Results

Embarrass River Basin

(Downstream from Proposed Reservoir)

Station No. 7 - Hwy. No. 1, 1 mile south of Lawrenceville Refinery on Indian Creek

Date	Chloride	Sulfate	Alkalinity	Hardness	Spec. Cond.	Dissolved Sol.	Turbidity	BOD (5 day)	pH	Temp.	DO	Coli/100 ml	Enteroc./100 ml	Radio-activity Alpha	Radio-activity Beta	Bacterial/ml	Syndets
7-28-59	1600	314	164	212	5450	3270	80	4.2	7.9	76	3.5	4,000	84	Tr.	Tr.	28,000	-
11-17-59	450	186	170	232	1870	1120	20	4.0	7.6	36	10.2	40	70	Tr.	Tr.	4,300	0.0
1-16-61	520	106	84	220	2040	1430	45	3.5	7.6	36	9.7	46,000	600	11	Tr.	100,000	0.0
9-5-61	3500	139	280	310	11500	6800	30	6.7	8.3	78	9.2	340	40	-	-	74,000	1.
2-14-62	820	108	124	320	3040	1840	15	3.9	7.6	44	12.0	1,700	0	5.5	58	14,000	0.4
8-21-62	1550	56	172	360	5470	3280	50	3.5	7.6	77	5.4	2,200	130	2.	92	22,000	0.3
5-28-63	1250	110	232	480	5700	5420	100	5.3	8.4	70	9.6	19,000	190	5.	43	58,000	0.6
8-27-63	3000	1350	320	1860	18900	11340	25	21.	8.0	72	5.4	750	4	0.0	0.0	5,000	1.1

Table 10

Future Municipal Water Supply Requirements
Embarrass River Basin

Municipality	Population			Per Capita Use GPCD			Total Municipal Use MGD		
	1960	1976	2010	1960	1976	2010	1960	1976	2010
Mattoon T. (Incl. Mattoon)	19,138	26,000	35,000	--	125 to 150	175 to 200	- -	3.2 to 3.9	6.1 to 7.0
Mattoon Only	19,038	24,000	31,000	79	125 to 150	175 to 200	1.50 - -	3.0 to 3.6	5.4 to 6.2
Charleston T. (Incl. Charleston)	11,924	20,000	28,000	--	125 to 150	175 to 200	-	2.5 to 3.0	4.9 to 5.6
Charleston Only	10,505	18,000	25,000	93	125 to 150	175 to 200	1.00	2.2 to 2.7	4.4 to 5.0
Toledo	998	1,200	1,700	40	75	125	0.05	0.09	0.21
Greenup	1,477	1,500	1,800	41	75	125	0.08	0.11	0.22
Wade T. (Incl. City of Newton)	4,270	6,500	9,500		125 to 150	175 to 200	- - -	0.8 to 1.0	1.6 to 1.9
Newton Only	2,901	4,500	7,200	86	125 to 150	175 to 200	0.25	0.5 to 0.7	1.3 to 1.4
St. Marie	347	380	450	52	75	125	0.02	0.03	0.06
Lawrenceville Bridgeport Sumner	5,492) 2,260) 1,035)	11,000*	16,000*	81	125 to 150	175 to 200	1.37 -	1.4 to 1.6	2.8 to 3.2

*Includes communities of Bridgeport and Sumner.

Future populations for the Communities of Toledo, Greenup, and St. Marie have been arbitrarily taken at a per annum rate of one half or one percent according to past growth. The population figures for these three communities are not based upon any economic factors and are not to be inferred as population projections or predictions. In the event the figures as used are erroneous, the error in anticipated needs will have only an insignificant effect upon the total needs for water from the Lincoln Reservoir.

Industrial

As indicated previously, industrial needs for water presently are satisfied from municipal supplies. It is not anticipated that the source of supply for the types of industries presently in the Embarrass River Basin will change. However, if any industries using large volumes are attracted to the basin, water use would increase at a rate greater than that computed for municipal needs. Therefore, the industrial needs for the larger communities are listed in Table 11. These communities represent locations where moderately large industrial water users would most likely locate in the Embarrass Basin. This tabulation of self-supplied industries, like that for municipal supply, is based upon the best estimates that can be made at this time. Revision of the figures in Table 11 may be required if further data become available.

Table 11

Industrial Water Requirements

Community	1960 MGD	1976 MGD	1980 MGD
Charleston	0	1.2 to 1.5	2.4 to 2.8
Lawrenceville	0	0.7 to 0.8	1.4 to 1.6
Mattoon	0	1.6 to 2.0	3.0 to 3.5
Newton	0	0.4 to 0.5	0.8 to 0.9
Total Industrial Needs	0	3.9 to 4.8	7.6 to 8.8

Water Quality Objectives

The water quality objectives used as a basis for determination of need for storage for regulation of streamflow for the purpose of water quality control are all related to the downstream land uses and in-stream uses of the waters. Where proper quality is not maintained, possible economic benefits may be foregone and the public health may be endangered. The objectives used in evaluating quality conditions in the Embarrass River Basin below the proposed Lincoln Reservoir have been based on present and prospective general recreational use of the Embarrass River, preservation of aquatic life, and its use as a source for raw water by the communities which might draw such supplies from the Embarrass River.

The bacterial coliform content is not used as an objective which could be achieved by additional storage. The cheapest solution to the bacterial content problem is considered to be chlorination of the effluent from waste treatment plants.

In setting water quality objectives for streams for the protection of aquatic life, mere survival is not enough. The minimum level selected

should be suitable for the continuous maintenance of satisfactory fish life and fish food organisms. Objectives are, therefore, based upon the environmental requirements of the fish species present in the river. On the basis of studies by the Public Health Service in the Cincinnati area, it was concluded that for a well-rounded, warm water fish population dissolved oxygen concentrations should not be below 5 mg/l for more than eight hours per day. Based on these considerations, a dissolved oxygen objective of 5 mg/l has been established for the Embarrass River below Lincoln Reservoir to preserve desirable aquatic life and to insure present and future recreational use of the river. The flows described as needed should achieve the dissolved oxygen objective in the river except that portion below Lawrenceville provided water of satisfactory quality is discharged from the Lincoln Reservoir. This could be achieved by multiple level outlets.

One of the declared public policies of the Sanitary Water Board Law is ". . . to provide that no waste be discharged into any waters of the State without first being given the degree of treatment necessary to prevent pollution of such waters . . ."[7]

It is further stated that ". . . Industrial wastes shall be treated or otherwise modified prior to discharge so as to maintain the following conditions in the receiving waters:

1. Freedom from anything that will settle to form putrescent or otherwise objectionable sludge deposits which interfere with reasonable water uses.

2. Freedom from floating debris, scum and other floating materials in amounts sufficient to be unsightly or deleterious.

3. Freedom from materials producing color or odor in such degree as to create a nuisance.

4. Freedom from substances in concentrations or combinations which are toxic or harmful to human, animal, or aquatic life.

These conditions to be maintained in the receiving waters following the discharge of industrial waste effluents are basic or minimum requirements . . ."

From an inspection of Table 12[8] it can be seen that all municipal wastes are or will be adequately treated. Adequate treatment at the present time amounts to 85 percent removal of the 5-day biochemical oxygen demand. Quantities of water required for water quality control have been computed on the premise that such treatment will be provided.

The most critical area of the Embarrass River, after construction of the proposed reservoir, will be at Newton. Located upstream from Newton and below the proposed reservoir are the small Communities of Greenup and Toledo. These communities can discharge adequately treated wastes into the Embarrass River which will carry releases from the proposed reservoir. The released flow will be adequate to assimilate such treated wastes and be of satisfactory quality for Newton's water supply if the releases are maintained at a rate equal to the minimum seven consecutive day average flow having a once in

Table 12

Municipal Waste Treatment
Embarrass River Basin

Municipality	1960 Population	Design Flow MGD	Average Flow MGD	Treatment	Discharge To
Bridgeport	2,260	0.02	0.25	Oxidation Ponds	Indian Creek
Casey	2,890	0.30	0.20	Sedimentation Trickling Filter	North Fork of Embarrass River
Charleston	10,505	1.00	1.45	Sedimentation Trickling Filter	Town Branch
Greenup	1,477	0.16	0.06	Imhoff Tank Trickling Filter	Embarrass River
Lawrenceville	5,492	1.00	0.55	Sedimentation Activated Sludge	Embarrass River
Lawrenceville airport*	5,000	0.50	0.35	Sedimentation Trickling Filter	Embarrass River
Martinsville	1,351	(New plant under construction)			
Mattoon	19,088	2.75	1.70	Sedimentation Activated Sludge	Kickapoo Creek
Newton	2,901	0.29	0.19	Imhoff Tank Trickling Filter	Embarrass River
Oblong	1,817	0.18	0.20	Sedimentation Activated Sludge	Big Dogwood Creek to Embarrass River
Sumner	1,035	0.06	0.20	Imhoff Tank Intermittent Sand Filter	Muddy Creek
Toledo	998	0.11	0.05	Oxidation Ponds	Cottonwood Creek to Embarrass River
Tuscola	3,875	0.61	0.25	Sedimentation Activated Sludge	Scattering Fork
Villa Grove	2,308	0.30	0.16	Sedimentation Activated Sludge	Embarrass River

*Potential only - Air Base presently closed.

five year frequency which is 21 cfs. This minimum release from the proposed Lincoln Reservoir will be ample to receive and assimilate Newton's adequately treated wastes.

It is believed this release rate is reasonable because minimum releases will be held constant for a prolonged period of time. Consequ the communities downstream will be deprived of the periodic small rises normally would be available to downstream users. Also, the release rat not inconsistent with other uses. The Fish and Wildlife Service has in a need for 50 cfs for preservation of fish life in the stream.

The last downstream community on the Embarrass River is Lawrence which is situated approximately eight miles from the mouth of the river there is no other water use downstream from Lawrenceville, it appears t the releases from the proposed reservoir increased by natural inflow wi be of sufficient quantity to receive and assimilate Lawrenceville munic wastes.

An inspection of Table 9, page 30, discloses a chloride problem on Indian Creek near Highway No. 1 Bridge, one mile south of Lawrencevi refinery. Other problems at that point are also indicated by hardness, specific conductance, dissolved solids, and coliform. It is believed t except for the coliform concentrations, most of the problem is due to l uses related to oil field operations and oil refinery operations. Oil pollution will be studied and reported upon at a later date. Needs for water pollution control and the plants, efforts, and expenditures by pr owners and local authorities to fill these needs will be described in d

Neither the adequacy of treatment or other methods of control of wastes at the source have been determined due to time limitations. There at this time needs for and value of storage for control of residual waste from oil field operations could not be determined. It is possible that there may be a greater need for water downstream from the Lincoln Reservoi than has been shown in this preliminary evaluation.

The State of Illinois has prepared "Basic Industrial Waste Disposal Requirements" which are set forth in Technical Release 20-11 dated May 1, 1960.

Table 13 lists the minimum needs for water quality control in the Embarrass River Basin.

Table 14 gives a summary of the needs for water supply and for quali control in the Embarrass River Basin

Table 13

Water Quality Control Needs in MGD

Municipality	1960	1976	2010
Newton			
To receive municipal wastes	0.5	1.6 to 2.0	3.3 to 5.7
To receive industrial wastes	---	0.8 to 1.0	1.6 to 1.8
Total requirement for water quality control	0.5	2.4 to 3.0	4.9 to 7.5
Design flow	13.6	13.6	13.6

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WABASH RIVER BASIN COMPREHENSIVE STUDY COVERING RESERVOIR SITES--ETC(U)

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Table 14

Summary of Needs

Community	1960 MGD	1976 MGD	2010 MGD
Charleston (Charleston T)			
Municipal Water Supply	0.98	2.50 to 3.00	4.90 to 5.60
Design Flow and Storage	----	----	3. 3.
Additional Need	----	----	1.9 to 2.6
Industrial Water Supply	----	1.2 to 1.5	2.4 to 2.8
Total Additional Need	----	0.7 to 1.5	4.3 to 5.4
Mattoon (Mattoon T)			
Municipal Water Supply	1.50	3.25 to 3.90	6.13 to 7.00
Design Flow and Storage	----	----	----
Additional Need	----	----	----
Industrial Water Supply	----	1.6 to 2.0	3.0 to 3.5
Total Additional Need	----	----	0.1 to 1.5
Newton (Newton T)			
Municipal Water Supply	0.25	0.8 to 1.0	1.6 to 1.9
1-Day Flow (Once in 30-Year Frequency)	----	0.84	0.84
Additional Need	----	0.0 to 0.2	0.8 to 1.1
Industrial Water Supply	----	0.4 to 0.5	0.8 to 0.9
Total Additional Needs	----	0.4 to 0.7	1.6 to 2.0
Quality Control Needs			
Total Needed to Receive Municipal and Industrial Wastes	0.5	2.4 to 3.0	4.9 to 7.5
Design Flow	13.6	13.6	13.6
(7-Day Once in 5-Years)	----	----	----
Additional Need	----	----	----
Lawrenceville			
Municipal Water Supply	0.77	1.4 to 1.6	2.8 to 3.2
Maximum Dependable Draft	----	----	----
Additional Need	----	----	----
Industrial Water Supply	----	0.7 to 0.8	1.4 to 1.6

Table 14 (Cont'd)

Summary of Needs

Community	1960 MGD	1976 MGD	2010 MGD
Lawrenceville (Cont'd)			
Total Additional Water Supply Needs	----	----	0.2 to 0.8
Quality Control Needs			
Total Needed to Receive Municipal and Industrial Wastes	1.5	4.2 to 4.8	8.4 to 9.6
Design Flow	13.6+	13.6+	13.6+
(7-Day Once in 5-Years)	----	----	----
Additional Need	----	----	----
Total Additional Water Supply Needs Directly From the Proposed Reservoir and Returned to the Reservoir as Adequately Treated Waste	----	0.7 to 1.5	4.4 to 6.9

The flow of 21 cfs is believed to be a reasonable flow for the Embarrass River and would be sufficient to meet the needs along the river as explained previously. To maintain a flow of 21 cfs (13.6 mgd) in the Embarrass River would require a draft on storage which could be provided by an impounding reservoir with 5,400 acre-feet of storage capacity. This draft on storage would be for water quality control purposes.

Plan for Supplying Future Requirements

The City of Mattoon has an impoundment that provides a safe yield of 9.0 mgd and is not expected to need more water in the near future but estimates of municipal and industrial needs indicate that as much as 1.5 mgd additional

water may be needed by the year 2010. This additional water can be obtained from the proposed Lincoln Reservoir by providing a useable storage volume of about 1,700 acre-feet. An alternate to the use of water from the proposed Lincoln Reservoir would be to construct a single-purpose reservoir on one of the small tributaries to the Embarrass or the Little Wabash Rivers.

The City of Charleston is expected to be in need of additional water by the year 1976 because of siltation of its reservoir on Embarrass River and the accompanying loss of storage volume. It is anticipated that Charleston will need additional water in the range of 0.7 to 1.5 mgd by 1976 and from 4.3 to 5.4 mgd by the year 2010. Useable storage volume of about 3,500 acre-feet in excess of the river flow and present storage would provide the quantity of water needed to give a firm yield of 5.4 mgd. Loss of existing reservoir volume by unexpectedly rapid siltation could create a need for additional water for Charleston much earlier than 1976.

An alternate to the use of water from the proposed Lincoln Reservoir would be the construction of a single-purpose water supply reservoir on one of the small tributaries of Kickapoo Creek or the Embarrass River.

Toledo, Greenup, and St. Marie use wells for water supply. It is anticipated, on the basis of presently available information, that these communities can obtain sufficient supply from ground water sources and should do so even though all are within a distance of the Embarrass River that would permit pumping Lincoln Reservoir releases from the Embarrass River if suitable quantity and quality of water is maintained in that stream.

The City of Lawrenceville uses wells for water supply. Formerly, Embarrass River water was used but because of oil field wastes the quality of river water was badly degraded and the city changed its water supply source to a well field in the outwash sands and gravels of the Wabash River. The existing wells used by Lawrenceville have a maximum dependable draft of 4.0 mgd and it is believed the well field can be expanded to satisfy the anticipated need of 0.2 to 0.8 mgd additional water. Alternate sources of supply for Lawrenceville could be obtained from the Embarrass River if suitable quality of water were maintained or from the Wabash River.

VII. BENEFITS OF STORAGE

Evaluation Method

The time available for the Lincoln Reservoir study permitted only a preliminary appraisal of needs for water supply and water quality control. In this preliminary appraisal, a range of needs has been determined on the basis of the best estimates that could be made in the available time. Greater needs than those that have been anticipated may develop.

The needs for water supply and water quality control can be met as they develop on a piecemeal basis, but a more efficient method would be to determine all the needs and supply them with a single multi-purpose project. The benefits realized by this latter method would be equivalent to the savings or the decrease in costs from the more expensive alternates to the single project.

Alternate Plans

An alternate plan could be used to provide water for municipal and industrial water supply in place of the multi-purpose Lincoln Reservoir. This plan would require the individual communities to provide their own separate water supplies. Water for quality control purposes would be supplied most economically from a single reservoir upstream from Charleston.

This alternate to the proposed multi-purpose Lincoln Reservoir would require the construction of an additional impoundment for Charleston or the enlargement of the present impoundment when the present reservoir capacity is no longer sufficient. Similarly, Mattoon would have to plan for additional water but possibly not before the year 2000. Newton, which

satisfies its water needs from the Embarrass River, would need only a token amount of storage to insure a firm yield equal to its estimated future needs.

The communities of Toledo, Greenup, and Ste. Marie would require additional supplies but not necessarily from a surface water source. It is assumed from the anticipated increase in needs that these three communities could satisfy their needs from ground water sources.

Lawrenceville might have its additional needs supplied by a single purpose reservoir on some tributary upstream or it could obtain water from the Wabash River. Until the oil field wastes are controlled, it seems wiser to plan on expansion of the existing well field to its ultimate capacity as necessary.

Water Supply Benefits

The costs of the cheapest alternate sources of supply for the communities in need of additional water may be taken as a measure of the minimum value of the benefits gained from the Lincoln Reservoir project.

It is anticipated that the city of Mattoon will need about 1700 acre-feet of useable storage to provide about 1.5 mgd additional water by the year 2010. An alternate to acquiring this storage in the proposed Lincoln Reservoir would be the construction of a single purpose water supply reservoir on a tributary stream. Small tributaries to Kaskaskia, Little Wabash, or Embarrass River are near to Mattoon which is situated on a divide. Because ground water supplies have been insufficient for Mattoon's needs, two impoundments have been built. Any new impoundment

is likely to require about four miles of pipeline. Use of water from the proposed Lincoln Reservoir would require from 10 to 12 miles of pipeline, or from 6 to 8 miles of pipeline more than would a nearby reservoir.

The cost of constructing a single purpose reservoir having a capacity of 1700 acre-feet would be about $800,000. Thus, the minimum value of benefits from the provision of storage of water for Mattoon's use would be that figure less the differential in pipeline cost, or about $550,000 in terms of 1963 dollars. Adjusted for operation and maintenance costs, amortized for a period of 50 years beginning in 1970, and discounted to the year 2000 when Mattoon's additional water supply need for increased safe yield is expected to begin, the minimum annual value of benefits to Mattoon would be about $10,000 per year. This minimum value reduced to an annual value would be about $79,000 per year.

No estimate of possible benefits has been made for the communities of Toledo, Greenup, and Ste. Marie because it is believed that existing and expanded well fields will be adequate to supply the needs of these communities. In view of the generally cheaper cost of treating well water, it is believed storage costs of a surface water supply would exceed the benefits.

The city of Newton is expected to need a dependable river flow of about 2.0 mgd in addition to the normal river flow in the year 2010. During the lowest flow of the Embarrass River in the period of record available, a token usable storage volume of 20 acre-feet would have given the necessary dependable flow in the Embarrass River and no benefit has been assessed for this token storage.

The city of Lawrenceville is expected to continue use of its existing well field to the year 2010 without need for water from an additional source.

Adjusted Value of Storage

The minimum value of storage required for water supply from the proposed Lincoln Reservoir is at least equal to the cost of the two single purpose reservoirs that would be required for Mattoon and Charleston less the difference in cost of pipeline to service Mattoon. This total adjusted value is about $1,850,000, or about $89,000 per year.

The amount of the annual benefits of the municipal and industrial water from the proposed reservoir has been computed by converting the net savings in capital cost to an annual basis by amortizing for 25 years at 4 per cent and converting to an annual basis for a 50-year period at 3 per cent beginning in 1970. Annual operation and maintenance costs of the alternate were added to this figure, and annual operation and maintenance of any necessary pipeline were deducted. The resulting benefit figure then was discounted to the year when the supply would become necessary.

It should be noted that the treated wastes of Mattoon and Charleston amounting to more than 100 per cent of water use from the proposed Lincoln Reservoir would be discharged into the proposed reservoir by way of Kickapoo Creek. The difference in water use and treated waste return is caused by the diversion of Mattoon's wastes from the Little Wabash River.

Water Quality Control Benefits

The critical point on the Embarrass River will be below Newton when the proposed Lincoln Reservoir is constructed. However, under existing

conditions, the water quality at and below the mouth of Kickapoo Creek is more critical. At this juncture, treatment plant effluent from Mattoon and Charleston enters Embarrass River.

After construction of the proposed Lincoln Reservoir, it is expected that these two cities will provide adequate treatment of their wastes.[9] Following this degree of treatment, no adverse affects would be expected in the main body of the proposed reservoir.

Downstream from the proposed reservoir, the city of Newton utilizes the Embarrass River as a source of supply. The flow believed to be reasonable for the users downstream from the Lincoln Reservoir is the minimum seven consecutive day average flow with a frequency of once in five years. This quantity has been selected because the periods of increased flow which presently are available to the downstream users will not occur with the same frequency and magnitude after construction of the proposed Lincoln Reservoir.

If this release rate from the reservoir is maintained, it is believed that adequately treated wastes from Greenup and Toledo can be assimilated without degrading the quality of the river at Newton below acceptable standards for water supply. Newton can then utilize the river for its supply and the remaining flow will be sufficient to receive and assimilate Newton's adequately treated wastes.

To maintain a flow of 21 cfs in the Embarrass River would require a draft on storage which could be provided by an impounding reservoir having a usable storage of 5400 acre-feet of water.

An alternate to the use of water from the proposed reservoir for quality control would be for the city of Newton to construct storage ponds for its wastes during periods when sufficient river flow is not available to assimilate the wastes. This alternate is not considered practical for the reason that possibly sixty days storage might be required and based upon projections, suitable sites for storage ponds of adequate size would not be available, and for a further reason that present State regulations would not compel Newton to use this method of control. Besides being impractical, this alternate would deprive downstream communities of river flow as an emergency source of water during fires. For the above reasons, this alternate is not recommended.

A second alternate would be for Newton to dispose of its wastes by distillation process. The process cost of this alternate would be prohibitive for Newton and is not required by the State. Therefore, this alternate is not satisfactory.

A third alternate for the community of Newton and other downstream communities, is the construction of a single-purpose reservoir from which stored water could be released to yield the desired flow. The storage draft that would be required would be 5400 acre-feet.

Downstream from Newton, the North Fork Embarrass River and other tributaries flow into the Embarrass River before that stream reaches Lawrenceville. On the basis of presently available information, it is believed that oil field wastes create a continually degraded condition in the Embarrass River from Lawrenceville to the mouth. Because of this degraded condition, it is not suggested that the Embarrass River be considered a

potential water supply source until this adverse condition is corrected. Further studies and investigations may indicate whether oil field wastes are receiving adequate treatment or whether other methods of controlling wastes are applied at the source.

When further studies are made, an analysis of oil field and refinery wastes can be made and the water quality of Embarrass River can be reconsidered in light of the data which then will be available.

At the present time, available information indicates that 21 cfs would be sufficient release from the proposed reservoir to maintain a suitable water quality in the river to the point downstream where brine wastes enter. Brine wastes control flows are not included in this estimate.

The minimum value of benefits to be derived from water quality control on the Embarrass River will be at least equal to the cost of a single purpose reservoir that would yield 21 cfs at the proposed Lincoln dam site. It is estimated that 5400 acre-feet of water storage would be required in such a reservoir. The cost of the single purpose structure would be about $1,600,000 as adjusted to 1963 construction costs by the index in Engineering News Record. This value would be about $80,000 annually.

In order to insure that water of satisfactory quality is released from the proposed Lincoln Reservoir, consideration should be given to multiple outlets. One should be in the upper levels, one at middle depth, and one in the lower levels. Otherwise, if water can only be released from levels near the bottom or below the thermocline, the quality of water may be poor owing to absence of dissolved oxygen and the presence of hydrogen sulphide as well as other undesirable traits.

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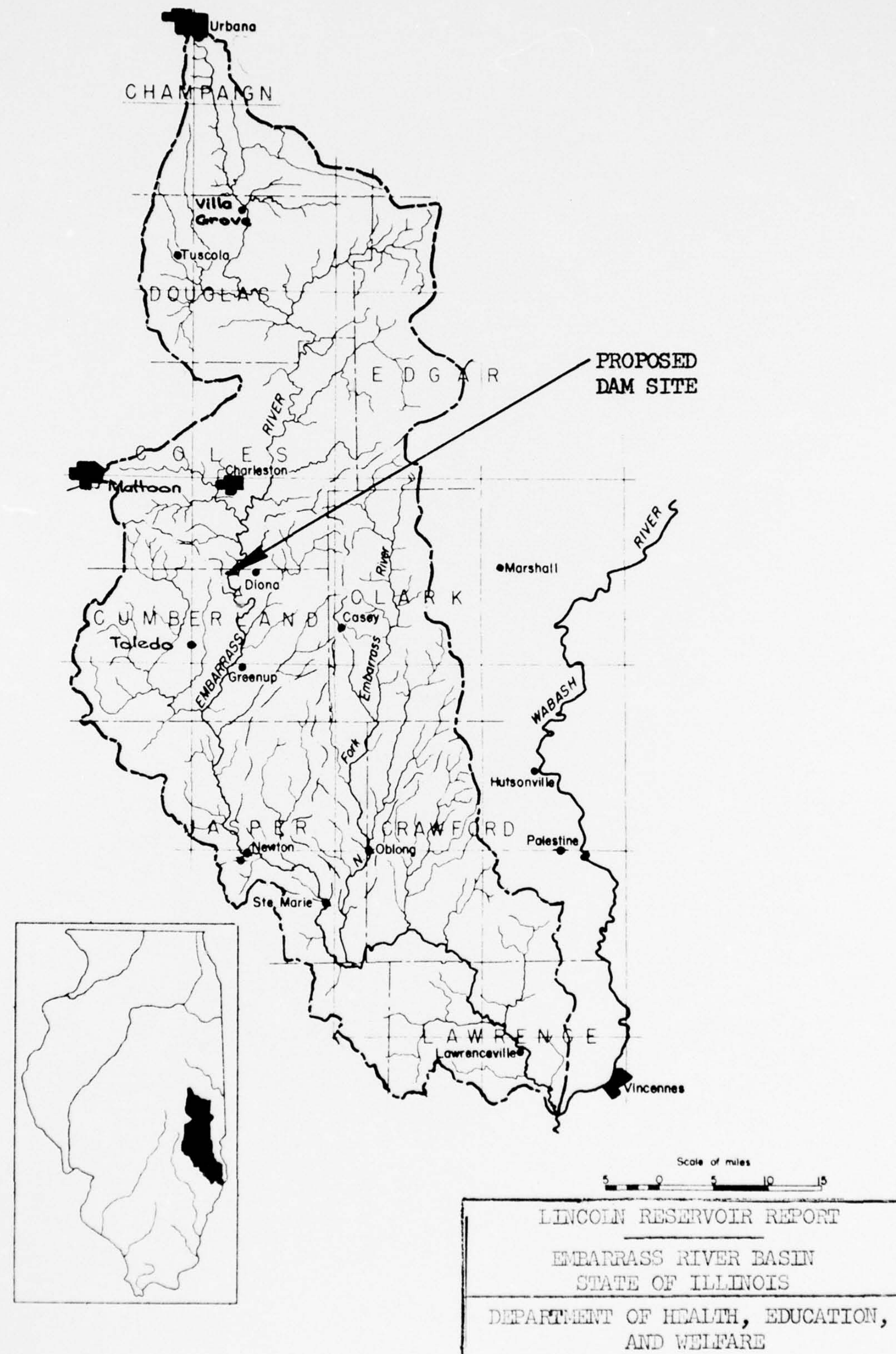

LINCOLN RESERVOIR REPORT

EMBARRASS RIVER BASIN
STATE OF ILLINOIS

DEPARTMENT OF HEALTH, EDUCATION,
AND WELFARE
PUBLIC HEALTH SERVICE

OHIO RIVER BASIN PROJECT
EVANSVILLE, INDIANA FIELD STATION

Map furnished through courtesy
of The U. S. Geological Survey.

FIGURE I

WATER RESOURCES STUDY
CLIFTY CREEK RESERVOIR
WABASH RIVER BASIN
INDIANA

A Preliminary Study of Potential Needs and Value of Water for Municipal, Industrial, and Water Quality Control Purposes

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region III
Ohio River Basin Project
Evansville Field Station, Indiana

In Cooperation With The

U. S. DEPARTMENT OF THE ARMY
U. S. Army Engineer District - Louisville, Kentucky

January 1964

EXHIBIT F-6

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I. INTRODUCTION

Authority

The authority to conduct studies of need and value of water for municipal, industrial, and water quality control purposes is provided in the Federal Water Pollution Control Act (Public Law 84-660, as amended by Public Law 87-88 in 1961) and in the Memorandum of Agreement, dated November 4, 1958, between the Department of the Army and the Department of Health, Education, and Welfare, relative to the Water Supply Act of 1958 (Title III of P.L. 85-500, as amended by P.L. 87-88).

In accordance with the above acts, the District Engineer, Corps of Engineers, Louisville, Kentucky, by letter dated August 20, 1963, requested the U. S. Public Health Service to furnish "...information in accordance with the work plan now under negotiation for your studies for the Wabash Basin Comprehensive Study...." The letter further stated "Deletion of the minimum pool at Clifty Creek will be considered because of the site's limited storage capability...unless you consider conservation storage to have greater value than flood control space...."

Purpose and Scope

This report assesses municipal and water supply needs for the Clifty Creek Basin in the counties of Bartholomew, Decatur, Rush, and Shelby Counties in Indiana, assesses surface water quality control needs, and estimates need for and value of water storage for regulation of the Clifty Creek flow for these needs for the years 1976 and 2010.

Due to time limitations, this study of the Clifty Creek Reservoir and its findings are considered to be preliminary and may require additional investigations and refinement prior to construction of the proposed project.

Acknowledgments

Completion of this study was made possible by the cooperation and assistance of Federal and State authorities and by local authorities in the basin. Information and data were furnished from their publications, records, and files.

Acknowledgment is made to the following agencies and their support is gratefully recognized:

U. S. Geological Survey

U. S. Soil Conservation Service

Indiana State Board of Health

Indiana Flood Control and Water Resources Commission

Wabash River Interstate Commission

City of Columbus

II. SUMMARY AND CONCLUSIONS

Summary

1. The proposed Clifty Creek Reservoir site is situated on Clifty Creek about $1\frac{1}{2}$ miles southwest of Hartsville and about 10 miles northeast of Columbus, Indiana.

2. Clifty Creek, which has a drainage area of about 200 square miles, is a tributary of the East Fork, White River and enters that stream at a point just south of Columbus. The mean flow of the creek at a point where the drainage area is 88.8 square miles was 106 cfs during 14 years of record from 1948 to 1962. During that period, zero flow was experienced at times during 1948, 1951-57, 1959, and 1961.

3. Communities near the proposed Clifty Creek Reservoir site are Greensburg, Hope, Hartsville, and Columbus. Of these, only Hartsville lies within the basin. Columbus, which is situated on the East Fork of White River, is growing rapidly eastward and will be affected to a greater degree than the other communities.

4. Seymour, about 27 miles downstream from Columbus, utilizes the river as its source of public water supply and requires a water quality suitable for that use.

5. The City of Greensburg is located on Sand Creek and would be expected to take its water supply from that source. The community of Hope is expected to require a source of supply. Even if it elects to take its supply [illegible] the proposed reservoir, the demand would be so small as to be insignificant with respect to storage computations.

Conclusions

1. It is expected that the population of the Columbus area (Columbus township including the city) will increase from about 30,000 in 1960 to about 40,000 by 1976 and about 73,000 by the year 2010.

2. It is expected that this area which used 3.5 mgd (million gallons per day) in 1960 will need from 7.0 to 8.0 mgd for municipal supplies and 3.5 to 4.0 mgd for industrial uses in 1976. By the year 2010, it is believed the needs for water will be about 14.6 to 16.4 mgd for municipal supplies and from 7.3 to 8.2 mgd for industrial purposes. This water can be obtained from the East Fork, White River in the event presently used well fields prove inadequate.

3. In addition to needs for municipal and industrial purposes, water will be needed in Clifty Creek and in the East Fork, White River for quality control. Water in the range of 6.5 to 7.2 mgd in 1976 and from 9.1 to 12.9 mgd in the year 2010 will be needed to assimilate adequately treated wastes introduced into Clifty Creek. This water can be obtained by an annual draft on storage of 11,000 acre-feet in the proposed Clifty Creek Reservoir. In addition, this released flow will augment the flow in the East Fork, White River so that a satisfactory water quality is maintained at Seymour.

4. No benefits of any significance can be attributed to storage for municipal and industrial water supply purposes.

5. Water released from the proposed Clifty Creek Reservoir seasonal pool in the amount indicated above in order to assure minimum discharges at the confluence of Duck Creek as shown in Table 14 would provide a savings of $1,885,000 to Columbus, Indiana (1963 Construction Cost Index). These savings are based upon the elimination of a force main, a lift station, and operation and maintenance costs of these facilities. In addition, benefits realized from increases in flow of the East Fork, White River during periods of natural low flow would have at least a minimum value of about $1,440,000 (1963 Construction Cost Index) based upon the cost of a single purpose reservoir which would assure the required flow in Clifty Creek. Amortized for 50 years at three percent and adjusted for operation and maintenance costs, these amounts are equivalent to annual values of $73,000 and $70,000 respectively, or a total value of $143,000 per year.

6. Flows released from the proposed Clifty Creek Reservoir could receive adequately treated wastes and provide water of satisfactory quality flowing through a residential area of East Columbus. It would improve the quality of water in the East Fork, White River thereby benefiting Seymour, Indiana by providing a better source of raw water supply. In addition, such flows would provide a quality of water which would enhance recreational opportunities and improve the aquatic environment in the East Fork, White River, the White River, and the Wabash River to the Ohio River.

III. DESCRIPTION OF PROJECT

Location

The Corps of Engineers is presently considering the Clifty Creek Basin as a possible site for a multi-purpose reservoir project. The proposed reservoir site under study is in Bartholomew and Decatur Counties, Indiana, on Clifty Creek, a tributary of East Fork of White River (See Figure I). Seventy percent (140 square miles) of the basin's total drainage area of 200 square miles is located above the proposed dam site. The dam site under consideration is approximately 18 stream miles above the mouth of Clifty Creek, $1\frac{1}{2}$ miles southwest of Hartsville, Indiana, and about 10 miles east by northeast of Columbus, Indiana.

Streamflow

The average discharge[1] of Clifty Creek at Hartsville for 14 years of record (February 1948 to September 1962) is 106 cfs from a drainage area of 88.8 square miles. Maximum and minimum mean daily flows experienced during the period of record were 6,180 cfs and zero flow respectively. Records indicate that for the gaging station at Hartsville, there have been periods of prolonged zero flow. In fact, zero flow has occurred at times during 1948, 1951-57, 1959, and 1961. For the 1962 water year, the mean discharge was 79.8 cfs. The expected minimum 7 consecutive day flow with a frequency of recurrence of once in 10 years is zero based upon a study of past records.[2]

Water Quality

There have been no water quality sampling stations located on Clifty Creek, thus no information is available as to the actual quality of the water and for the purpose of this report, it is assumed Clifty Creek water will be of a similar quality to that of Big Blue River near Carthage, Muscatatuck River near Austin, and Laughery Creek near Osgood. Table 1[3] lists the results of analysis of samples collected at the above quality monitoring stations for the year 1962. These areas were selected because of their similarity and proximity to the Clifty Creek Basin. There are no municipal wastes (raw or treated) being discharged into Clifty Creek above the proposed dam site; therefore, it is mainly for this reason that the quality of the water is expected to be acceptable for all legitimate uses.

Before this information can be used in final design, the water quality of the stream must be determined by a program of sampling and analyses.

Pertinent Data

Storage volumes tentatively selected by the Corps of Engineers for the purpose of this study are as follows: minimum pool would provide 7,655 acre-feet of storage at elevation 705 feet and useable seasonal storage would provide 10,860 acre-feet of water at elevation 720 feet.*

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*This seasonal water storage is a temporary storage provided in the lower part of the flood control pool in the summer months when flood control storage needs are less.

Table 1[3]

Water Quality Results*
Monitoring Stations near the
Clifty Creek Reservoir Project

Station	Big Blue River near Carthage			Laughery Creek near Osgood			Muscatatuck River near Austin		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
Alkalinity as CaCO3	152	301	260	56	228	153	60	174	124
Chlorides as Cl	7	27	16	3	27	11	3	24	10
Nitrates as N	0.5	5.4	2.0	0.1	3.1	0.7	0.1	2.2	0.7
pH	7.3	8.6	8.1	7.5	8.8	8.2	7.0	8.3	7.8
Specific Conductance	421	1105	633	158	547	362	143	513	330
Hardness as CaCO3	173	370	315	88	290	178	74	214	150
Color	5	25	10	5	40	20	-5	50	15
Turbidity	5	700	55	5	500	50	5	600	65
Susp. Matter	2	588	56	3	422	41	5	845	71
Vol. Susp. Matter	0	108	14	0	42	10	0	76	12
BOD	0.6	7.7	2.3	0.5	6.2	2.8	1.3	9.3	3.2
DO	6.5	12.8	9.9	4.3	14.0	9.1	0.0	12.0	7.0

*Results from approximately 28 samples per station collected during the year 1962. All results are given in mg/l except pH, color, turbidity and specific conductance. The latter unit is in μmhos/cm.

The proposed seasonal pool would be filled in April and May each year and would be held at or as near as possible to 720 feet considering that water must be discharged from the reservoir as shown on Table 14. After Labor Day, the seasonal pool would be drained at a rate which would bring the water surface to the minimum pool elevation by December 1.

IV. DESCRIPTION OF STUDY AREA

Location and Boundaries

The Clifty Creek Basin is located in the southeastern part of the State of Indiana, approximately 50 miles southeast of Indianapolis, and lies generally in a northeast and southwest direction (See Figure I). Clifty Creek has a watershed drainage area of 200 square miles in parts of four counties: Bartholomew, Decatur, Rush, and Shelby. The basin is about 40 miles in length and varies in width from 3 to 10 miles.

Formed by the merging of three streams (North Branch, Middle Branch, and South Branch) in its upper reaches, Clifty Creek extends southwesterly to its junction with the East Fork, White River just south of Columbus. One of the principal tributaries is Fall Fork, which enters Clifty Creek just above the proposed dam site. Duck Creek, another main tributary, enters the Clifty Creek about 5 miles downstream from the proposed dam. Another tributary, Otter Creek, enters Clifty Creek about 8 miles below the proposed dam site and south of the small community of Petersville.

Geography

The terrain of the Clifty Creek Basin is generally level to rolling. Near the mouth of the stream, the topography is moderately flat. Around Hartsville the terrain becomes moderately steep and gradually levels to rolling topography up to the confluence of the three tributary branches. The branches of the creek develop in moderately steep terrain.

Clifty Creek has a fall of about 320 feet in a distance of approximately 40 miles from its beginning at the confluence of the contributing branches to the junction with the East Fork, White River. More than 70 percent of this fall occurs above the community of Hartsville in a distance of about 20 miles.

Due to the above features, it is observed that Clifty Creek has one of the highest rates of runoff of any gaged stream in the Upper East Fork of the White River Basin.[4]

Climate

Temperatures[5] are fairly consistent throughout the basin. At the lower end of the drainage basin, based upon 78 years of record, Columbus has a mean annual temperature of 54.4°, a mean monthly high (July) of 76.5°, and a mean monthly low (January) of 32.4°. Near the upper end of the Clifty Creek Basin, Greensburg, with 65 years record, has a mean annual temperature of 53.4°, a mean monthly high (July) of 75.9°, and a mean monthly low (January) of 31.0°. The extreme low of 35.0° below zero was registered at Greensburg on February 2, 1951.

Precipitation records[5] for Columbus, based on 78 years of record, list a mean annual of 41.24 inches, a mean monthly high (June) of 4.12 inches, and a mean monthly low (October) of 2.51 inches. Greensburg, with 66 years of precipitation records, has experienced a mean annual precipitation of 41.06 inches, a mean monthly high (June) of 4.32 inches and a mean monthly low (August) of 2.57 inches.

Principal Communities and Industries

At the present time, only one incorporated community, Hartsville, is located within the Clifty Creek Basin. Hartsville borders on Clifty Creek and is approximately 20 stream miles from its mouth. The city of Columbus and the communities of Greensburg and Hope are located near to and will be affected by the proposed reservoir, therefore they are considered in this report. Columbus is situated near the mouth of Clifty Creek, and a southeast corner of the city lies within the basin. Hope is located 4 miles northwest of the proposed reservoir and just outside of the basin's drainage area. Greensburg is outside of the watershed and approximately 12 miles northeast of the proposed reservoir.

The majority of all industrial activity is located in or near the communities of Columbus and Greensburg with Columbus having the greater amount. An engine factory, an office furniture manufacturer, and a canning factory are some of the larger industries in Columbus. Greensburg has an aluminum and brass company and a packing plant.

V. ECONOMY

Present Economy

Area Included

The area of influence of the proposed Clifty Creek Reservoir Project includes all or part of six counties in southern Indiana. These six counties are: Bartholomew, Daviess, Jackson, Knox, Lawrence, and Martin.

Agriculture

Farming is important to the over-all economy of the study area. In 1960, agriculture accounted for 11,755 employees or 16.2 percent of all employment and this was a decrease of 2.6 percent from the 18.8 percent of 1950. In the State, agricultural employment had declined from 11.6 percent in 1950 to 6.5 percent in 1960. Value of farm products sold in the study area more than doubled between 1939 and 1959 as measured in constant dollars. The number of farms in the area declined but this was in line with the National trend toward the consolidation of farms into larger units.

Indices of Agricultural Activity
1939 - 1959

Year	Farms	%Change	Acres Harvested	% Change	Value of Products Sold*	% Change
1939	12,100	-59.0	590,000	+5.0	$26,300,000	+109.0
1959	5,000		620,000		$55,000,000	

*Expressed in constant monetary terms.

Mineral Industries

The mineral wealth of the study area consists of clays, coal, cement, gypsum, petroleum, natural gas, sand, stone, and gravel. The value of the mineral output from the six-county study area was $18,695,000 or 9 percent of the State's total mineral output. There were 2,100 workers engaged in mineral activities in 1950. In 1960, there were only 750 workers in mineral activities. The 750 workers represented only 1 percent of the total employment in the study area in 1960.

Value of Mineral Output, 1960

County	Minerals		Value of Output
Bartholomew	Stone		$ 533,000
Daviess	Clay, sand, gravel		261,000
Jackson	Clay, sand, gravel		204,000
Knox	Coal, sand, gravel		3,759,000
Lawrence	Stone, cement		10,066,000
Martin	Gypsum, clay, stone		3,187,000
		Subtotal	$18,010,000
Daviess	Crude petroleum		327,000
Knox	Crude petroleum		358,000
		Subtotal	$ 658,000
		Grand Total	$18,695,000

Manufacturing

Manufacturing accounted for about 29 percent of the total employment in the study area in 1960 which was an increase of only 2 percent over 1950 (See Table 2). However, value added by manufacture in 1958 totaled $184,400,000, an increase of 26 percent over 1954 as measured in constant dollars.

The distribution of manufacturing plants according to industry and employee size is shown in Table 3. Over half of the plants employed less than 20 people in 1960, but according to the 1958 Census of Manufactures, there was one plant in the area which employed over 1,000 employees. Over 75 percent of manufacturing employment was in the manufacture of durable goods. The non-electrical machinery industry employment more than doubled between 1950 and 1960, and with 5,526 employees in 1960, employed more than double the number of employees of any other industry in the durable goods category. Each of those industries, however, employed at least 1,100 employees. Food and kindred products and apparel accounted for the majority of employment in the non-durable goods category.

Table 4 summarizes the manufacturing plant information from the 1958 Census of Manufactures in each county and indicates the possible high water intake plants and potential waste producers. All plants are included which had over 100 employees and whose 4-digit Standard Industrial Classification code industry is included in the listing of industries with an intake of over 20 million gallons per year in the Industrial

Table 2

Industrial Labor Force
Clifty Creek Reservoir Project
1950 - 1960

	1950	% of C.E.[a]	1960	% of C.E.[a]
Total Civilian Employment	68,219	100.0	72,725	100.0
Agriculture	12,795	18.8	11,755	16.2
Mining	2,069	3.0	748	1.0
Construction	3,256	4.8	3,843	5.3
Non-Commodity Industries	31,542	46.2	35,038	48.2
Transportation[b]	4,889	7.2	3,631	5.0
Trade	12,410	18.2	12,988	17.9
Finance	1,120	1.6	1,633	2.2
Services	7,538	11.0	10,200	14.0
Government	5,585	8.2	6,586	9.1
Manufacturing	18,557	27.2	21,341	29.3
Durables	13,635	20.0	16,228	22.3
Furniture-Lumber-Wood	2,522	3.7	1,960	2.7
Primary Metals	1,947	2.9	1,618	2.2
Fabricated Metals	915	1.3	1,161	1.6
Non-Electric Machinery	2,200	3.2	5,526	7.6
Electrical Machinery	2,993	4.4	2,323	3.2
Transportation Equipment	946	1.4	1,400	1.9
Miscellaneous	2,112	3.1	2,240	3.1
Non-Durables	4,922	7.2	5,113	7.0
Food & Kindred Products	1,642	2.4	1,495	2.1
Textiles	343	.5	13	----
Apparels	1,345	1.9	1,421	1.9
Printing & Publishing	321	.5	569	.8
Chemicals	547	.8	907	1.2
Miscellaneous	724	1.1	708	1.0

[a]Civilian Employment

[b]Includes Communications and Utilities

Table 3

Manufacturing Plants by
Major Industry and Employment Size
Clifty Creek Reservoir Project
1958

Industry	Employment Size (1-19)	Employment Size (20-99)	Employment Size (100-249)	Employment Size >250	Total	Percent of Total
Food & Kindred Products	29	17	5		51	19.2
Tobacco Products						
Textile Mill Products						
Apparel & Related Products	1	1	3	3	8	3.0
Lumber & Wood Products	31	6			37	14.0
Furniture & Fixtures	2	1		2	5	1.9
Paper & Allied Products	1	3	1	1	6	2.3
Printing & Publishing	19	7			26	9.8
Chemicals & Allied Products	4	2	2		8	3.0
Petroleum & Coal Products	2				2	.8
Rubber & Plastic Products		2			2	.8
Leather & Leather Products	1		1	3	5	1.9
Stone, Clay, & Glass Products	24	10	6	2	42	15.8
Primary Metals Products	3	1		2	6	2.3
Fabricated Metal Products	13	2	5		20	7.5
Non-Electric Machinery	15	5	1	3	24	9.0
Electrical Machinery	4	1	1	3	9	3.4
Transportation Equipment	2	1	4	2	9	3.4
Instruments & Related Products		1			1	.4
Miscellaneous Manufacturers	4				4	1.5
Total	155	60	29	21	265	100.0
Percent of Total	58.5	22.6	10.9	8.0	100.0	

Table 4

Summary of Manufacturing Plants
by Selected Counties, 1958
Clifty Creek Reservoir Project

BARTHOLOMEW COUNTY — 70 Plants; 16 over 100 Employees

SIC* Code	Industry Description	Number Plants	Employment Range	National Average Water Intake per Employee per Year in Gallons
	High Water Intake Plants			
2033	Canned Fruits & Vegetables	1	100-249	552,000
3111	Leather Tanning & Finishing	1	100-249	655,000
3321	Gray Iron Foundries	1	500-999	489,000
2021	Creamery Butter	1	1-19	1,724,000
2094	Grease & Tallow	1	1-19	1,786,000
2421	Sawmills & Planning Mills	4	1-19	2,852,000
3273	Ready-Mixed Concrete	1	20-49	1,386,000
	Potential Waste Producers			
2011	Meat Packing	1	1-19	582,000
2015	Poultry Dressing	1	1-19	422,000
2015	Poultry Dressing	1	20-49	422,000
2026	Fluid Mills	1	1-19	356,000

JACKSON COUNTY — 48 Plants; 10 over 100 Employees

SIC* Code	Industry Description	Number Plants	Employment Range	National Average Water Intake per Employee per Year in Gallons
	High Water Intake Plants			
2631	Paperboard Mills	1	100-249	8,840,000
2421	Sawmills & Planning Mills	7	1-19	2,852,000
2821	Plastic Materials	1	100-249	2,810,000
2834	Pharmaceutical Preparations	1	100-249	422,000
2892	Explosives	1	50-99	1,355,000
3273	Ready-Mixed Concrete	1	1-19	1,386,000
3717	Motor Vehicles & Parts	2	100-249	242,000
3717	Motor Vehicles & Parts	1	250-499	242,000
	Potential Waste Producers			
2011	Meat Packing	1	1-19	582,000
2015	Poultry Dressing	1	1-19	422,000
2026	Fluid Mills	1	50-99	356,000
2033	Canned Fruits & Vegetables	1	50-99	352,000
2042	Prepared Animal Feeds	1	20-49	584,000

*Standard Industrial Classification code.

Water Use Survey, 1958 Census of Manufactures. Plants with fewer than 100 employees are listed only if the industrial water intake per employee for their SIC category was very high, as shown in Table 4.

Non-Commodity Industries

Non-commodity employment in the study area made up about the same proportion of 48.2 percent total employment as it did in the state in 1960. It had increased 2 percent in ten years as compared to a 2.8 percent increase in the state, but there had been some changes in the importance of the different industries in the group. Transportation employment had declined 2.2 percent which service employment had increased 3 percent.

Income

Median family income in the study area was $4,616* in 1959, an increase of 86 percent over 1949. The state median family income in 1959 was $5,798 with an increase of 80 percent over 1949. Income in the area has been gaining on the higher income figure in the state but is still behind. However, because many of the families in the study area are associated with farming and get a portion of their income in farm products which are not included in the Census income figure, the real income in the area may not be as low as indicated by the difference between the state and study area figures.

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*Census of Population

Population

The growth of population for the decades from 1930 through 1960 has been on a modest upward sweep. The 1930 Census tabulated 163,926 residents in the study area, which comprised 5.1 percent of Indiana's population. At the end of 1960, population had climbed 18 percent since 1930 to 194,123, representing 4.2 percent of the state population. For those years (1930-1960) population growth in the basin outpaced the national growth rate of 11.4 percent, but was outdistanced by Indiana's growth rate of 22 percent.

The study area remains under-urbanized compared to the State of Indiana and to the Nation. At the 1960 Census, 43.6 percent, or 84,689, of the area's population was classified as urban; 56.4 percent was classified as rural-farm and rural non-farm. However, in Indiana urbanization was reported at 62.4 percent and the Nation urbanized sectors accounted for 70 percent of the population.

Of the seven cities in the economic study area, five have populations in excess of 10,000. Columbus is the largest city with a population of 20,778 in 1960.

Projected Economy

Projections of the economy of the Clifty Creek study area were derived from determining historical trend relationships between the study area and the state, and projecting those relationships using, as the basis, projections for the state prepared by the National Planning Association,

Washington, D. C. Past trends were modified in accordance with judgment based on additional information. These projections are of a preliminary nature and may be modified, if necessary, upon receipt of the Arthur D. Little Company economic base study report for the Ohio River Basin

Employment Projections

Table 5 shows employment projections to 1976. Manufacturing employment is projected to increase. Employment in commodity production, however, will decline as a proportion of aggregate labor force. Non-commodity and service-utility industries will gain more prominence in employment size and in percentage share of the over-all labor force.

Population Projections

Population growth is projected to surpass past performance (See Figure II). The study area, though not expected to match national and state rates of growth,.will experience population expansion. In 2010, the study is expected to number about 330,000 in population which is an increase of 37.5 percent compared to the 1960 Census of 240,000.

Table 6 lists projections for major urban districts within the basin. It is anticipated that future growth will concentrate in those areas where present population density is most pronounced.

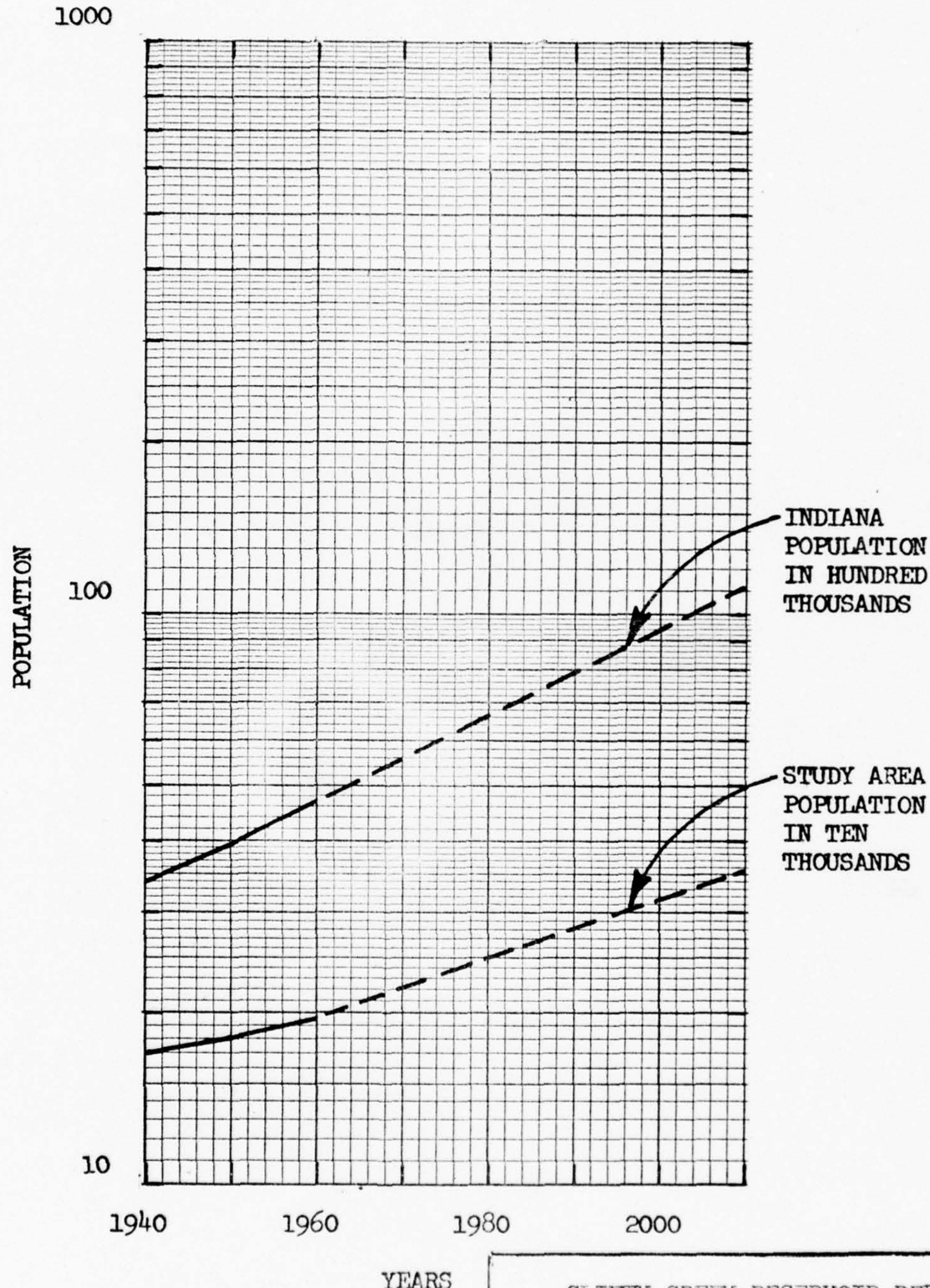
Table 5

Economic Projections
Clifty Creek Reservoir Project
1960 - 1976

	1960	% of C.E.[a]	1976	% of C.E.[a]
Total Civilian Employment	72,725	100.0	96,160	100.0
Agriculture	11,755	16.2	8,800	9.1
Mining	748	1.0	700	.7
Construction	3,843	5.3	6,500	6.8
Non-Commodity Industries	35,038	48.2	53,000	55.2
Transportation[b]	3,631	5.0	5,000	5.2
Trade	12,988	17.9	19,500	20.3
Finance	1,633	2.2	2,400	2.5
Services	10,200	14.0	16,700	17.4
Government	6,586	9.1	9,400	9.8
Manufacturing	21,341	29.3	27,160	28.2
Durables	16,228	22.3	21,350	22.2
Furniture-Lumber-Wood	1,960	2.7	1,800	1.9
Primary Metals	1,618	2.2	1,850	1.9
Fabricated Metals	1,161	1.6	1,500	1.6
Non-Electric Machinery	5,526	7.6	7,500	7.8
Electrical Machinery	2,323	3.2	3,500	3.6
Transportation Equipment	1,400	1.9	2,200	2.3
Miscellaneous	2,240	3.1	3,000	3.1
Non-Durables	5,113	7.0	5,810	6.0
Food & Kindred Products	1,495	2.1	1,900	2.0
Textiles	13	--	10	--
Apparels	1,421	1.9	700	.7
Printing & Publishing	569	.8	1,100	1.1
Chemicals	907	1.2	1,200	1.2
Miscellaneous	708	1.0	900	.9

[a]Civilian Employment

[b]Includes Communications and Utilities



CLIFTY CREEK RESERVOIR REPORT

POPULATION PROJECTIONS

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

OHIO RIVER BASIN PROJECT
EVANSVILLE, INDIANA FIELD STATION

FIGURE II

Table 6

Population Projections
Clifty Creek Reservoir Project
1976 - 2010

	1950	% Change	1960	% Change	1976	% Change	2010
United States	151.3 mil.	18.5	179.3 mil.	28.3	230.0 mil.	87.0	430.0 mil.
State of Indiana	3.9 mil.	20.5	4.7 mil.	34.0	6.2 mil.	77.5	11.0 mil.
Study Area (Bartholomew, Daviess, Jackson, Knox, Lawrence, and Martin Counties)	180,000	7.8	194,000	23.7	240,000	37.5	330,000
Columbus Township (Incl. Columbus)	23,000	30.4	30,000	33.3	40,000	82.5	73,000
Columbus Only	18,000	16.7	21,000	42.9	30,000	100.0	60,000
Jackson Township (Incl. Seymour)	12,000	8.3	13,000	38.5	18,000	66.7	30,000
Seymour Only	10,000	20.0	12,000	33.3	16,000	68.8	27,000

VI. WATER REQUIREMENTS

As the population increases and industrial growth occurs, greater demands will be made for water. Hence, the growth projected in the preceding section supports the projections of increased water needs.

Past and Present Water Use

Municipal

Presently there are no public water supplies within the basin, but there are three municipalities just outside of the basin and within its influence that do have public water supplies. These communities are Columbus, Greensburg, and Hope. Their water use is listed in Table 7.[6]

Industrial

In the past, the major portion of industrial water consumption has been supplied from municipal systems. Presently there are a few moderately heavy industrial water users that have their own water systems. These industries obtain their supplies from well fields. No data are available at this time from self-supplied industries pertaining to the quantity or the pre-treatment of water supplies for industrial use.

Water Pollution Control

The communities of Columbus and Greensburg are the only municipalities within the influence of the Clifty Creek Basin that presently have waste treatment facilities. Table 8[7] lists information pertaining to these treatment facilities.

Table 7

Municipal Water Systems[6]
Clifty Creek Reservoir Project

Municipality	1960 Pop.	Source	Treatment	Rated Plant Capacity (mgd)	Average Plant Output (mgd)	Demand (gpcd)
Columbus	20,778	Wells	Iron removal Filtration Chlorination	6.00	3.50	168
Greensburg	6,605	Wells and Flatrock Creek	Iron removal Filtration Chlorination	2.00	1.00	151
Hartsville	399	(No municipal water system)				
Hope	1,489	Wells	Chlorination	0.5	0.08	54

Table 8

Municipal Waste Treatment[7]
Clifty Creek Reservoir Project

Municipality	1960 Pop.	Design Flow (mgd)	Average Flow (mgd)	Treatment	Discharge to
Columbus	20,778	5.30	3.89	Activated sludge Chlorination	East Fork, White River
Greensburg	6,605	0.80	0.70	Activated sludge Chlorination	Sand Creek

At the present time the community of Hope has no waste water treatment works. However, the town does have a combined sewer system which discharges the liquid wastes of the community into Haw Creek, a tributary of the East Fork, White River. It is expected that in the future, Hope will construct a municipal waste treatment plant that will discharge its effluent into Haw Creek.

It is expected that Greensburg will continue to discharge treated wastes to Sand Creek, a tributary of the East Fork of White River. Therefore, the municipal wastes of the town will present no area of concern for water quality control within the Clifty Creek Basin.

The community of Hartsville has no sewerage system at this time, but it is expected that the community will provide waste treatment facilities when its waste load becomes sufficiently great to compel construction. The effluent from such a plant could conceivably enter the proposed reservoir.

Columbus now discharges its treated effluent into the East Fork, White River. This plant also treats the wastes from Bakalar Air Force Base located north of the city of Columbus.

Several industries within the study area, but outside of the Clifty Creek drainage basin, have their own treatment facilities. The discharges from these treatment works do not enter into the watershed of Clifty Creek.

Existing Sources

As previously mentioned, there are no municipal water systems within the basin itself but for those communities near the basin, wells

are the chief source of public water supply. Generally ground water of good quality and dependable quantity becomes increasingly difficult to obtain proceeding upstream in the basin.[8] Information furnished by the U. S. Geological Survey indicates that the ground water is pumped from sand and gravel and bedrock aquifers. The bedrock aquifers are usually of limestone and yield from less than 20 to more than 100 gpm (gallons per minute) with a dissolved solids total of less than 400 mg/l (milligrams per liter). The sand and gravel aquifers yield from 20 to more than a 1000 gpm with a dissolved solids total of less than 350 mg/l.

A detailed study of the availability of ground water at Columbus will be required before a more accurate statement can be made concerning the uses of ground water in that area.

Columbus, prior to 1951, obtained its water supply from the East Fork, White River. The change to ground water supplies was made due to the savings in cost of building a new iron removal plant and utilizing wells as compared to remodeling of the then existing obsolete surface water treatment plant. The maximum dependable draft from the present well field is reported to be about 6.0 mgd[6] from sand and gravel aquifers.

The community of Hope obtains its ground water from sand and gravel and bedrock aquifers. This present well system has an estimated maximum dependable draft of 0.50 mgd.[6] This amount is becoming insufficient to meet Hope's increasing demands.

Twelve miles northeast of the proposed reservoir and just outside of the Clifty Creek Basin is the community of Greensburg. The public water system is supplied from wells located in sand and gravel and bedrock aquifers, and an impoundment of Flatrock Creek. Impounded safe yield and the maximum dependable ground water draft has been recorded as 2.0 mgd and 1.0 mgd respectively.[6]

The ranges of raw water quality for the municipalities of Columbus, Greensburg, and Hope are listed in Table 9.[9]

Additional Water Needs

Municipal

The water demand for the communities in or near the Clifty Creek Basin will vary with the economy of the area and with the availability of water. Table 10 lists the communities and shows estimated future per capita and municipal use. This table is based upon the best estimates of water use that can be made at this time. If more detailed and reliable data become available, it may become necessary to revise this tabulation.

Table 10 includes such light industrial water users that may be expected to be served from municipal supplies.

Future population figures for the communities of Hartsville and Hope are not based upon any economic factors and are not to be inferred as population projections or predictions.

Table 9

Quality of Municipal Water Supplies (Raw Water) within the Influence of the Clifty Creek Reservoir Project

Municipality		Columbus	Greensburg Surface Water*	Greensburg Ground Water	Hope
ph		7.1	7.9	7.6	7.1
Color		0-15	30	0-35	0-5
Turbidity		7	2500	15	0-10
Hardness as CaCo3	(mg/liter)	320	132	450	280-410
Calcium as Ca	(mg/liter)	80		115	100
Magnesium as Mg	(mg/liter)	30		40	35
Sodium as Na	(mg/liter)	2		10	7
Potassium as K	(mg/liter)	1		1	1
Iron as Fe	(mg/liter)	1.3	2.6	2.7	0-0.3
Manganese as Mn	(mg/liter)	0.2		0.4	0
Alkalinity (total) as CaCO3	(mg/liter)	260	102	360	250-360
Chlorides as Cl	(mg/liter)	6	4	11	5-15
Sulfates as So4	(mg/liter)	50		85	55
Nitrates as N	(mg/liter)	- 1	- 2	- 2	0-4.4
Fluorides as F	(mg/liter)	0.1	0.3	0.3	0.1-0.5

*1 Sample

Table 10

Future Municipal Water Supply Requirements
Clifty Creek Reservoir Project

Municipality	Population			Per Capita Use (gpcd)			Total Municipal Use (mgd)		
	1960	1976	2010	1960	1976	2010	1960	1976	2010
Greensburg	6,605	9,000	15,000	151	175 to 200	200 to 225	1.00	1.7 to 1.8	3.0 to 3.4
Hartsville	339	560*	1,100*	--	75 to 100	125 to 150	--	0.04 to 0.06	0.1 to 0.2
Hope	1,489	2,100*	3,700*	54	75 to 100	125 to 150	0.08	0.15 to 0.2	0.5 to 0.6
Columbus T. (Incl. Columbus)	30,000	40,000	73,000	--	175 to 200	200 to 225	--	7.0 to 8.0	14.6 to 16.4
Columbus Only	20,778	30,000	60,000	168	175 to 200	200 to 225	3.50	5.3 to 6.0	12.0 to 13.5

*Not to be inferred as a population projection.

Industrial

The majority of industrial water needs will continue to be satisfied from municipal sources. If any industries using large volumes of water are attracted to the basin, the water use would increase at a rate greater than that computed for the municipal needs. The industrial needs for the larger communities of Columbus and Greensburg are listed in Table 11. These communities are within the influence of the Clifty Creek Basin and represent the locale where moderately large industrial water users would most likely locate. The tabulation for industrial water requirements is based upon the best estimates that can be made at the present time. Revision of this table may be required as further data become available.

Water Quality Objectives

The water quality objectives used as a basis for determination of need for storage for regulation of streamflow for purpose of water quality control are all related to the downstream land uses and instream uses of the waters. Where proper quality is not maintained, possible economic benefits may be foregone and the public health may be endangered. The objectives used in evaluating quality conditions in the East Fork, White River below Clifty Creek have been based on East Fork, White River's use as a source of raw water for Seymour, Indiana, preservation of aquatic life, and present and future general recreational use. Clifty Creek flows through a desirable residential area of Columbus, Indiana. If a waste treatment plant is built along Clifty Creek, there must be an adequate

Table 11

Industrial Water Requirements
Clifty Creek Reservoir Project

Community	Year		
	1960	1976	2010
Greensburg	--	0.6 to 0.7	1.3 to 1.5
Columbus	--	3.5 to 4.0	7.3 to 8.2
Total Industrial Need	0	4.1 to 4.7	8.6 to 9.7

quantity of good quality of receiving waters to accept the treated wastes, in order that the stream be esthetically acceptable and that no offensive odors be caused from further degradation of treated wastes.

The bacterial coliform content is not used as an objective which could be achieved by additional storage for regulation of streamflow. Chlorination of treated effluent is considered to be the cheapest solution. However, it should be recognized that not all wastes containing bacteria are collectable, for instance storm water overflows and street washings.

The distance (time of travel) between the waste treatment outfall and the nearest downstream water intake for municipal use must also be considered. Seymour, Indiana is approximately 27 miles downstream from Columbus, Indiana

In setting water quality objectives for streams for protection of aquatic life, mere survival is not enough. The minimum level selected should be suitable for the continuous maintenance of satisfactory fish life and fish food organisms. Objectives are therefore based upon the environmental requirements of the fish species present in the river. On the basis of Public Health Service studies in the Cincinnati area, it was concluded that for a well-rounded, warm water fish population, dissolved oxygen concentrations should not be below 5 mg/l for more than 8 hours per day of any 24-hour period.

Based upon the location of the raw water intake of Seymour, Indiana; the need to perpetuate a warm water fish habitat, the use of the East Fork, White River for general recreation, and the need to make Clifty

Creek esthetically acceptable to the residential population of Columbus, Indiana, the following water quality objectives have been used in determination of needs for storage:

1. Dissolved oxygen--a minimum of 4 mg/l and an objective of 5 mg/l.
2. Biochemical oxygen demand--not more than 5 mg/l.
3. The waters should not contain any toxic, taste-producing, or otherwise harmful substances, or organisms not readily and completely removable by ordinary water treatment. Raw waters should be free of excessive amounts of acid, microscopic organisms, and organic matters causing any interference with normal operation and efficiency of water treatment processes.
4. The waters released from the proposed Clifty Creek Reservoir should be of the best quality available in the reservoir during the critical hot summer and fall season. This objective could be achieved by the use of multi-level outlets; one in the upper levels, one at mid-depth, and one in the lower levels. Such discharges would assist in making Clifty Creek esthetically acceptable in the residential area of East Columbus, Indiana.

Water Quality Control

It is assumed in this preliminary evaluation that all municipal and industrial wastes discharged into Clifty Creek will be treated to the extent that 85 percent of the 5 day 20°C Biochemical Oxygen Demand (BOD) will be removed. Quantities of water required for water quality control are computed on the premise that such treatment will be provided.

Hartsville, as it begins to grow at a greater rate than in the past because of its location on the proposed reservoir, will require waste treatment facilities. This community would then discharge its adequately treated effluent into the watershed of the proposed reservoir.

The communities of Greensburg and Hope would continue to use other streams outside of the Clifty Creek Basin for the receiving of treated municipal wastes.

The area in Clifty Creek which will be of greatest concern after construction of the proposed reservoir will be below the mouth of Duck Creek and near the vicinity of Columbus, Indiana. The city is presently experiencing a growth toward the east and in the watershed of Clifty Creek. This eastward growth is expected to continue for some time. Consultants for the city have made a study and recommend that a waste water treatment plant be located on Clifty Creek to serve this growing area.[10]

Table 12 lists the minimum needs for water quality control in the Clifty Creek Basin.

Table 12

Water Quality Needs
Clifty Creek Reservoir Project

Municipality	Predicted Population			Estimated Sewage Flow (mgd)			Estimated Streamflow Regulation Requirements (mgd)		
	1960	1976	2010	1960	1976	2010	1960	1976	2010
Eastern Sector of Columbus	----	9,000	16,400	----	1.6 to 1.8	3.3 to 3.7	----	6.5 to 7.2	9.1 to 12.9
Columbus Township (Incl. Columbus and the Eastern Sector of Columbus)	30,000	40,000	73,000	----	10.5 to 12.0	22 to 25	----	48 to 55	103 to 113

About 27 miles downstream from Columbus on the East Fork, White River, the community of Seymour obtains its water supply from the river. Therefore, the quality of water in the East Fork, White River must be satisfactory for Seymour's need which may become as much as 6 mgd based on the predicted population for the year 2010. The flow release from the proposed reservoir augmented by the flows of downstream tributaries on Clifty Creek will supplement the natural flow of the East Fork, White River thereby providing more water for the dilution of wastes discharged at Columbus. This dilution should be sufficient to give the stream assimilative properties to provide satisfactory water quality for the Seymour water supply.

Summary of Needs

The following table, Table 13, gives a summary of the needs for water supply and for quality control in the Clifty Creek Basin.

The range of needs for water for quality control shown in Table 13 are for the summer season in Clifty Creek. An indication of the seasonal variation in these water quality needs is given in Table 14.

Plan for Supplying Future Requirements

The dependable ground water draft and impounded storage is expected to be sufficient to satisfy Greensburg's municipal needs although the industrial needs may be as much as 1.5 mgd by 2010. It is believed that enlargement of the existing well field or impoundment can supply this additional need.

Table 13

Summary of Needs
Clifty Creek Reservoir Project

Community	1960 (mgd)	1976 (mgd)	2010 (mgd)
Hartsville			
Municipal Water Supply	--	0.04 to .06	.1 to .2
Design Flow and Storage	--	--	--
Additional Need	--	0.04 to .06	.1 to .2
Greensburg			
Municipal Water Supply	1.00	1.7 to 1.8	3.0 to 3.4
Maximum Dependable Draft and Storage	3.0	3.0	3.0
Additional Need	--	--	0 to 0.4
Industrial Water Supply	--	0.8 to 0.9	1.5 to 1.7
Total Need	--	--	1.5 to 2.1
Hope			
Municipal Water Supply	0.08	.15 to .2	.5 to .6
Maximum Dependable Draft	0.5	0.5	0.5
Additional Need	--	--	0 to 0.1
Columbus (Columbus Township)			
Municipal Water Supply	3.5	7.0 to 8.0	14.6 to 16.4
Maximum Dependable Draft	6.0	6.0	6.0
Additional Need	--	1.0 to 2.0	8.6 to 10.4
Industrial Water Supply	--	3.5 to 4.0	7.3 to 8.2
Total Need	--	4.5 to 6.0	15.9 to 18.6
Columbus (Columbus Township)			
Quality Control Need			
To Receive Wastes from Eastern Sector of City	--	6.5 to 7.2	9.1 to 12.9
Design Flow (Clifty Creek Seven day once in ten years)[2]	0	0	0
Additional Need in Clifty Creek	--	6.5 to 7.2	9.1 to 12.9

Table 13 (Continued)

Summary of Needs
Clifty Creek Reservoir Project

Community	1960 (mgd)	1976 (mgd)	2010 (mgd)
To Receive Wastes from Entire Columbus Area*	--	48 to 55	103 to 113
Design Flow (East Fork, White River at Columbus - Seven consecutive day once in ten years)[2]	49	49	49
Total Need for Quality Control	--	0 to 6	54 to 64
Water Needs from proposed reservoir and flow of downstream tributaries	--	6.5 to 7.2	9.1 to 12.9

*Draft on storage in the year 2010 to assure the above flows is estimated to be 11,000 acre-feet.

Table 14

Seasonal Variation in Water Quality Control Needs Clifty Creek Reservoir Project

Season	Minimum Seasonal Need in CFS 1976	2010
Winter	6	10
Spring	7	12
Summer	12	20
Fall	12	20

The community of Hope will most likely expand its well field to accommodate the future additional needs. However, if the community does choose surface supplies for its water needs, it could probably construct or utilize impoundments close to Hope more economically than it could use the proposed reservoir.

Columbus is expected to continue using ground water as long as dependable quantity and satisfactory quality exist. If the need should arise for the return to surface water supplies, the city would utilize the East Fork, White River as its source. The minimum daily discharge since 1948 of the East Fork, White River at the gaging station at Columbus was 87 cfs. This quantity would provide ample supply for the city's needs.

Hartsville, as previously mentioned, does not have a municipal water system at the present time. As the community grows and reaches the point where a municipal water system becomes necessary, it could utilize the proposed reservoir as an impoundment for its water needs.

The streamflow requirements needed for quality control, as shown in Table 14, are based on the premise that smaller quantities of water are needed for quality control during the winter months. Because of lower temperatures, it is expected that inflow from downstream tributaries will contribute a greater amount of flow to Clifty Creek during the spring months with a resulting increase in flow available for assimilation of adequately treated waste water from the eastern sector of Columbus. Releases from the seasonal pool of the proposed Clifty Creek Reservoir would be increased from June, when the seasonal pool is scheduled to be filled, to the end of November, when the seasonal pool will be empty.

The quantity of water estimated for Clifty Creek is needed to prevent the adequately treated wastes from the future plant on Clifty Creek from degrading the water quality of that stream so that it is esthetically undesirable through the reach expected to be heavily urbanized.

The releases from the proposed Clifty Creek Reservoir will enter the East Fork, White River about 2 miles downstream from the present Columbus disposal plant. At the mouth of Clifty Creek, the BOD loading on the East Fork, White River will be the same whether one or two sewage plants are used for Columbus.

Because of the need for satisfactory water supply for Seymour, a sufficient flow in the river is necessary to assimilate properly treated wastes from Columbus. Even though 85 percent of the BOD is removed from the wastes, additional water is needed for quality control. It is anticipated that the quantity of flow available from releases of the seasonal pool will provide the additional flow unless Columbus changes its source of supply to the East Fork, White River as its sole source. In that event, a higher degree of treatment of wastes may be required or a greater quantity of water will be needed for quality control purposes because of decrease in the water remaining in the river.

The time available for this report has not permitted a study to establish a definite need in specific amounts of additional water for quality control purposes in the East Fork, White River as a result of Columbus utilizing the river as a water supply source. That need has not, therefore, been considered at this time in estimating future requirements.

VII. BENEFITS OF STORAGE

Evaluation Method

Due to time limitations, the study reported herein is a preliminary appraisal of needs for water supply and for water quality control. It has been determined that on the basis of presently available information, existing sources for water will be sufficient to meet the anticipated future needs of Columbus for municipal and industrial purposes. For that reason, only water quality control needs in the Columbus area is considered further in the evaluation.

Owing to the distance from the proposed reservoir to Greensburg, it is believed on the basis of presently available information that Greensburg can expand its present source of supply more economically than it can obtain water from the proposed reservoir.

The community of Hope, which is situated adjacent to and northeast of the basin, is expected to require additional water by the year 1976; but it is believed the existing well field can be enlarged sufficiently for the anticipated needs. If surface supplies become necessary, an impoundment closer to Hope will prove to be more economical than will the use of Clifty Creek Reservoir. If Hope did elect to use the proposed reservoir for a source of supply, its needs would be so small as to be insignificant with respect to reservoir storage computation. Therefore, the needs of that community are not considered further in this evaluation.

Hartsville, which is situated adjacent to the proposed reservoir site, presently has no municipal supply. If this community should elect to use a surface water source from the reservoir, its expected rate of consumption would be small and would have little effect upon the water storage needs that are considered in the reservoir design.

In view of the above water supply conditions, water for quality control needs in the Columbus area is the determining factor in the evaluation of benefits. The benefits that will result from the storage of water will equal the difference in cost of adequate waste treatment with one treatment plant, a lift station at Clifty Creek, and a trunk sewer from the lift station to the sewage treatment plant as compared to the cost of two sewage treatment plants, one of which would be on Clifty Creek.

Alternate Plans

Two general procedures of disposing of adequately treated wastes from Columbus have been considered. These approaches to the problem are indicated below.

A. Provide a lift station and trunk sewer to the main Columbus sewage treatment plant on the East Fork of White River.

B. Construct a sewage treatment plant on Clifty Creek to eliminate the need for the lift station, trunk sewer, and pumping costs. This would require a sufficient flow in Clifty Creek for water quality control purposes.

Alternate B affords two choices of obtaining water for quality control purposes. Plan B-1 would provide water for quality control from a single purpose reservoir upstream from the critical area which is downstream from the mouth of Duck Creek. Plan B-2 would provide water for quality control from the proposed multipurpose Clifty Creek reservoir.

Plan A would require treatment of all wastes in a central sewage treatment plant that would discharge into the East Fork of White River. As discussed previously, the flow of the East Fork, White River at Columbus is not sufficient to afford proper assimilation of adequately treated wastes from Columbus if the anticipated water supply is taken from the river in the year 2010. A quantity of water which will assure 5 mg/l of dissolved oxygen is also necessary to provide water for quality control in the river between Columbus and Seymour. This quantity would assure a proper quality for the raw water supply for Seymour, Indiana.

Plan A would afford less water for quality control than Plan B unless a similar amount of storage to that afforded by Plan B were provided for increasing minimum flows. Plan A also would require the installation of a lift station in the eastern sector of Columbus that now is developing along Clifty Creek, and it would require the installation of a trunk sewer from the lift station to the central treatment plant. This construction has been estimated to cost about $1,885,000 (1963 Construction Cost Index) more than a treatment plant situated on Clifty Creek.

Plan B-1 would decrease the BOD loading imposed on the East Fork, White River between Columbus and the mouth of Clifty Creek, and this would result in a better dilution of effluent from the main treatment plant. Also, because of the draft on storage during minimum stages of the Creek, the flow of the East Fork, White River below the mouth of Clifty Creek would be increased. This increase would result in some improvement of the water quality of the river downstream from the mouth of Clifty Creek.

Plan B-2 would offer the same advantages over Plan A as would Plan B-1. Because the needs for water for quality control can be satisfied from seasonal storage and because seasonal storage makes possible multiple use of identical storage space, the cost of storage required for Plan B-2 will be more economical than Plan B-1. For these reasons Plan B-2 is considered the most logical approach to satisfying the needs for water quality control in Clifty Creek and in East Fork, White River. The combination of seasonal storage and natural flow at the confluence of Duck Creek would assure the desired flows without increasing the actual construction cost of the proposed Clifty Creek Reservoir other than for a special multiple level outlet structure which would be needed to assure the discharge of the desired quality of water from the reservoir.

Water Supply Benefits

It is not anticipated at this time that any community except Hartsville will find it economically advantageous to use the proposed Clifty Creek

Reservoir as a source for municipal supply. Because Hartsville's needs would not cause any major revision in storage requirements inasmuch as its adequately treated waste water would be returned to the proposed reservoir, water supply benefits are not considered to be significant in this analysis.

Water Quality Control Benefits

Clifty Creek will need water for quality control in order to make possible a separate sewage treatment plant on Clifty Creek for the eastern sector of Columbus. A study for the city of Columbus made by an engineering consulting firm has indicated that a savings of about $1,885,000 in terms of 1963 dollars would result from the construction of this plant instead of a lift station and trunk sewer to the plant on the East Fork of White River. This savings adjusted for maintenance and operation costs and amortized at 3 percent for a period of 50 years would equal an annual cost of about $73,000 per year. Consequently, the minimum value of benefits to Clifty Creek from the release of water from the proposed Clifty Creek Reservoir would be $73,000 per year based on savings to Columbus, Indiana on elimination of trunk sewers and lift stations.

The release of this water from the proposed seasonal pool would increase the flow of the East Fork of White River and increase the assimilative capacity of that stream from the mouth of Clifty Creek to Seymour. As a result, the water quality of Seymour's source of supply would be improved. A single purpose reservoir with a storage capacity equivalent to that of the seasonal storage of the proposed Clifty Creek Reservoir,

about 11,000 acre-feet, should be expected to cost about $1,440,000 (1963 Construction Cost Index). Adjusted for operation and maintenance and amortized for 50 years, the $1,440,000 in cost would be equivalent to an annual cost of about $70,000. Thus, the minimum value of benefits to the East Fork, White River above Seymour would be about $70,000 per year. The total minimum value of annual benefits to Clifty Creek and to the East Fork, White River would be about $143,000.

The flows released from Clifty Creek also would improve the water quality over its present quality of the East Fork,White River downstream from Seymour and the White River to the Wabash River and, to a degree, the quality of the Wabash River to the Ohio River.

In the event that the entire water supply for the Columbus area is taken from the East Fork, White River, releases from the seasonal pool will not be sufficient to maintain the water quality at a level desirable for use as a water supply by Seymour. If conditions become changed to such an extent that more water is needed for quality control, a re-evaluation of benefits can be made. Additional flow can be obtained by converting some seasonal storage to a conservation pool. Because this measure would reduce flood control benefits to some small extent and is not needed at this time, it should await a definite need.

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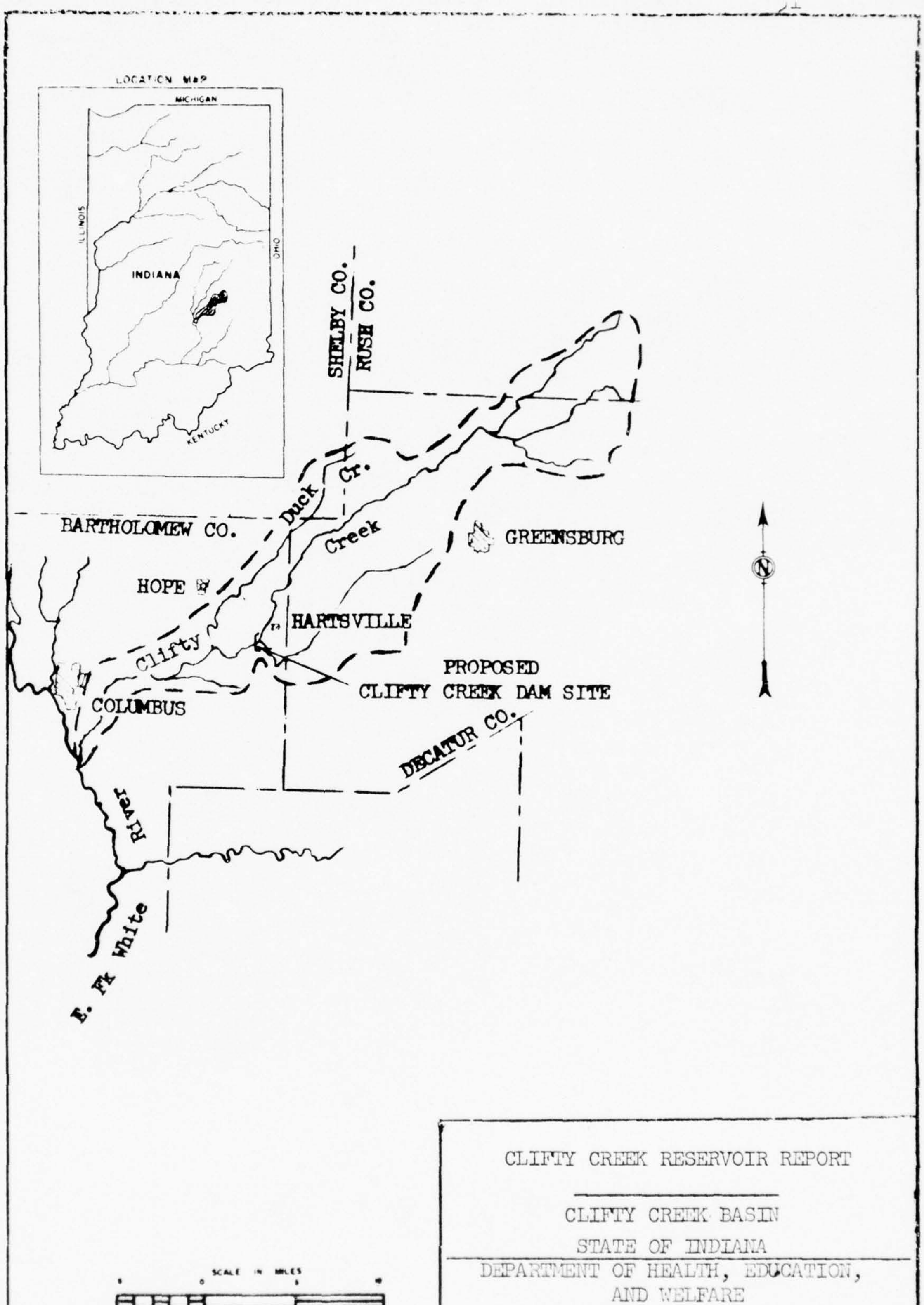

CLIFTY CREEK RESERVOIR REPORT

CLIFTY CREEK BASIN
STATE OF INDIANA

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

OHIO RIVER BASIN PROJECT
EVANSVILLE, INDIANA FIELD STATION

FIGURE I

WATER RESOURCES STUDY
PATOKA RIVER RESERVOIR
WABASH RIVER BASIN
INDIANA

A Preliminary Study of Potential Needs and Value of Water for Municipal, Industrial, and Water Quality Control Purposes

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region III
Ohio River Basin Project
Evansville Field Station, Indiana

In Cooperation With The

U. S. DEPARTMENT OF THE ARMY
U. S. Army Engineer District - Louisville, Kentucky

January 1964

EXHIBIT F-6

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I. INTRODUCTION

Authority

Authority to conduct studies of needs and value of water for municipal, industrial, and water quality control purposes is provided in the Federal Water Pollution Control Act (Public Law 84-660, as amended by Public Law 87-88 in 1961) and in the Memorandum of Agreement, dated November 4, 1958, between the Department of the Army and the Department of Health, Education, and Welfare, relative to the Water Supply Act of 1958 (Title III of P.L. 85-500 as amended by P.L. 87-88).

In accordance with the above acts, the District Engineer, Corps of Engineers, Louisville, Kentucky, by letter dated August 20, 1963, requested the U. S. Public Health Service to furnish "...information in accordance with the work plan now under negotiation for your studies for the Wabash Basin Comprehensive Study...." The letter cited recommendations by the Indiana Flood Control and Water Resources Commission and further stated "Your confirmation of this proposal, or differing estimate of needs and benefits, perhaps for a range of storage, will be needed for our project formulation...."

Because of time limitations, a preliminary appraisal study only of the Patoka Reservoir has been made.

Purpose and Scope

This report assesses municipal and industrial water supply needs for the Patoka River Basin, assesses surface water quality control needs, and estimates need for and value of water storage for regulation of Patoka River flow for these needs for selected years in the period 1960 to 2010. The Patoka River Basin is situated in Crawford, DuBois, Gibson, Martin, Orange, Pike, Spencer, and Warrick Counties in southwestern Indiana.

Acknowledgments

Completion of this study was made possible by the cooperation and assistance of Federal and State authorities and by local authorities in the basin. Information and data were furnished from their publications, records, and files.

Acknowledgment is made to the following agencies:

U. S. Geological Survey

U. S. Soil Conservation Service

Indiana State Board of Health

Indiana Flood Control and Water Resources Commission

Wabash River Interstate Commission

City of Huntingburg

City of Jasper

City of Princeton

Town of Oakland City

Town of Winslow

II. SUMMARY AND CONCLUSIONS

Summary

1. The proposed Patoka Reservoir site is in the upper reaches of the Patoka River Basin, the proposed dam site being in Dubois County about 12 miles northeast of Jasper near the south-central portion of Indiana.

2. The communities of Jasper, Huntingburg, Winslow, Oakland City, and Princeton are affected by the quantity and quality of water in the Patoka River.

3. The poor quality of Patoka River water tends to discourage its use by Huntingburg, Oakland City and Princeton. Winslow uses the river as a source of supply even though the water is essentially treated sewage.

4. Jasper uses its impoundment on Beaver Creek to augment the natural flow of the Patoka River for its water supply. The dependable yield of the combined natural flow and impoundment release is 3.0 mgd. Huntingburg's source of supply is an impoundment which has a safe yield of 0.65 mgd. Oakland City has two impoundments but their safe yield is unknown.

5. The Patoka River has had no flow for seven consecutive days more often than once in ten years. As a result, at times in nearly every year, the stream is of poor quality downstream from Jasper. In addition to municipal and industrial wastes, acid mine wastes flow into the river at points from above Winslow to below Princeton. Oil field wastes also enter the river above Princeton.

Conclusions

1. It is expected that the urban population along or near the Patoka River will increase from 25,000 in 1960 to about 54,000 by the year 2010.

2. The area along the Patoka River where improvement in quality and increased quantity is of major concern is in, and will continue to be in, the Jasper-Huntingburg area. These cities as well as the downstream communities of Winslow, Oakland City, and Princeton would be benefited by the availability of an increased flow to provide an improved raw water quality for municipal water supplies. The improved quality would also provide a satisfactory aquatic environment in a large part of the river. While benefits discussed apply primarily to the Patoka River, widespread benefits to water quality will also be realized along reaches of the Wabash River below Mt. Carmel, Illinois and to a lesser extent along the Ohio River downstream from the mouth of the Wabash River.

3. A quantity of water sufficient to meet the municipal and industrial needs of Jasper and the quality control needs below Jasper will be sufficient to provide a suitable quality of raw water for a source of municipal supply and would satisfy the needs of Huntingburg, Winslow, and Oakland City.

4. Jasper is expected to have a dependable water supply for municipal needs until 1976 but industrial uses are expected to require an extra 1.3 mgd in addition to 15 mgd needed for cooling purposes in 1976. By the year 2010, Jasper will need 5.4 mgd from new storage for municipal and industrial supply in addition to 15 mgd for cooling purposes or 20.4 mgd total for municipal and industrial use. Water needed for water quality control downstream from Jasper is expected to be 21.1 mgd in 1976 and

43.6 mgd in the year 2010. Of these needed flows, 15 mgd may be that water used at Jasper for cooling purposes.

5. The draft on storage for municipal and industrial use would be 600 acre-feet in 1976 and 2,800 acre-feet in the year 2010. The draft on storage for the cooling water needs would be 9,400 acre-feet. For quality control purposes, the draft on storage would be about 13,400 acre-feet in 1976 and 37,600 acre-feet in the year 2010.

6. The value of benefits attributable to storage for municipal and industrial purposes in the proposed Patoka Reservoir is equal to the capital cost of individual reservoir systems for each community and annual maintenance and operation costs. The annual value of the benefits of water released from storage for municipal and industrial uses has been estimated to be about $53,000. The value of water for cooling purposes has been estimated to be $35,000 annually. The value of benefits attributable to storage for water quality control purposes in the proposed reservoir is at least equal to the capital costs and operation and maintenance costs of a single purpose reservoir. The minimum value of these benefits have been computed to be about $160,000 annually. The total annual value of benefits for municipal and industrial use, including cooling, and for water quality control purposes is $248,000.

III. DESCRIPTION OF PROJECT

Location

The Corps of Engineers is presently studying the feasibility of a reservoir site in the upper reaches of the Patoka River Basin (See Figure I). The dam site under study is located in Dubois County about twelve miles east and four miles north of Jasper near the center of the southern portion of the state.

Streamflow

The average discharge[1] of the Patoka River at Jasper for 14 years of record is 381 cubic feet per second (cfs) from a drainage area of 257 square miles. A gage has been operated at a point on the river near the dam site, drainage area 171 square miles, for about two years. At this gaging station site the mean discharge for the 1962 water year was 190 cfs. The corresponding mean annual discharge at the Jasper gage was 292 cfs. Minimum daily discharge for the two locations were 0.3 and 1.3 cfs respectively. The expected minimum 7 consecutive day flow with a frequency of once in 10 years and the minimum daily discharge with a frequency of recurrence of once in 30 years is zero based upon a study of past records.

Water Quality

No information has been collected relative to the water quality at the project site but because there are no urban areas of significant

size between the project site and Jasper, it has been assumed for the purpose of this study that water quality would be similar to that at the Jasper water supply intake except during periods of low flow when releases from the Jasper water supply impoundment on Beaver Creek are used to clean and fill the pool on the Patoka River from which water is pumped to the Jasper water treatment plant.

Table 1 gives the results obtained from samples taken at a river monitoring station at Jasper in 1963. Table 2[2] gives a range in values for the years 1957-60 for a monitoring station near Princeton.[3]

Samples were taken from various points along the Patoka River on October 23 and October 24, 1963, in order to determine the dissolved oxygen and the biochemical oxygen demand. Data obtained from analyses of these samples are shown in Table 3. The flow of the stream was only incidentally increased by releases from Beaver Creek Reservoir. Water was being released on a twice a week schedule to flush leaves from the pumping pool and to fill that pool for the day by day withdrawals.

Table 1
Water Quality Monitor Station Patoka River at Jasper *

Date	Laboratory Analyses													Field Tests			
	Alkalinity (total) as $CaCO_3$, mg/liter	Chlorides as Cl— mg/liter	Nitrates as N mg/liter	pH	Spec. Conductance μmhos./1cm	Hardness as $CaCO_3$, mg/liter	Color	Odor—Qualitative **	Turbidity	Susp. Matter mg/liter	Vol. Susp. Matter mg/liter	BOD mg/liter	Coliform per 100 ml.	Temperature—C.°	Dissolved Oxygen mg/liter	Dissolved Oxygen % Sat.	pH
1-7-63	72	5	0.8	7.7	240	114	10	O	10	15	6	1.8	700	0	15.0	103	
2-18-63	76	3	0.4	7.2	239	122	5	O	5	5	5	1.4	100	1	16.5	115	
3-4-63	62	3	2.6	7.6	205	96	10	O	230	706	94	2.3	17,000	3	9.2		
3-19-63	26	2	1.6	7.0	106	44	20	O	120	132	18	2.1	3,000	10	9.0	80	
4-1-63	44	2	0.6	7.5	177	76	20	Ds	30	48	6	1.2	2,200	13	7.8	73	
4-15-63	74	3	3.7	7.5	236	100	15	O	10	27	6	1.5	300	14	9.9	96	
4-29-63	82	1	0.6	7.8	176	90	15	M	40	61	10	1.4	16,000	16	7.2		
5-13-63	74	2	0.7	7.9	221	96	10	O	200	31	19	1.8	53,000	17	6.0	62	
5-27-63	86	2	0.3	8.1	229	106	5	Ch	40	36	7	1.1	3,800	17	6.6	68	
6-10-63	64	4	0.0	7.4	177	100	10	O	30	47	13	4.2	4,200	25	5.4	65	
6-24-63	96	5	0.4	7.3	270	-	15	O	15	18	6	6.6	700	22	4.3	48	
7-8-63	62	1	1.7	7.5	168	72	20	A	50	96	13	3.4	40,000	22	4.7	53	8.3
7-22-63	86	5	0.6	7.8	258	134	5	O	30	17	13	2.4	17,000	25	5.7	68	8.8
8-5-63	82	9	0.3	7.4	251	60	20	M	30	13	8	2.4	1,100	28	6.3	80	8.1
8-19-63	79	6	0.2	7.8	193	90	15	O	50	22	4	1.7	120,000	20	1.6	17	8.2
9-3-63	74	8	0.5	7.4	239	40	20	O	70	44	14	4.3	1,650,000	23	4.5	52	8.0
9-16-63	94	18	0.8	7.9	302	116	5	E	10	11	6	4.3	1,000	22	9.0	102	8.2
9-30-63	108	16	0.4	7.5	328	306	5	O	30	16	5	3.1	26,000	17	5.0	51	7.9
10-14-63	112	18	0.1	7.6	348	148	10	O	30	18	7	2.6	4,100	20	4.7	52	8.3
10-28-63	118	16	0.4	7.7	384	176	25	O	40	25	9	5.3	1,400,000	16	2.1	21	7.2

*From unpublished data in files of Indiana State Board of Health.

**Code: O = No odor detectable; Ds = Septic; M = Musty; Ch = Hydrocarbon; A = Aromatic; E = Earthy

Table 2

Water Quality Monitor Station, Patoka River Near Princeton
Summary of Analyses 1957-60

Flow cfs	pH Range	Alkalinity* Range mg/1	Hardness mg/1** Range	Specific Conductance Range
0-10***	4.8	12	2000	
11-24	3.2 to 5.4	Acid 400 to Alkaline 56	972 to 2310	1800 to 3227
25-44	4.0 to 7.4	Acid 150 to Alkaline 44	586 to 1900	307 to 3362
45-69	5.8 to 6.3	10 to 70	554 to 1400	----
70-99	4.2 to 7.4	0 to 54	84 to 970	284 to 2823
100-124	6.9 to 7.0	4 to 93	458 to 1250	190 to 2431
125-200	4.6 to 7.4	0 to 51	320 to 757	682 to 1513

*Total as CaCO3
**As CaCO3
***Single sample

Table 3

Summary of Data
Patoka River Basin

October 23 & 24 1963

Station Location on river	Time Oct. 23, 1963	Air Temp. °C	Water Temp. °C	DO Mg/1	BOD Mg/1
State Road 65 near Princeton	9:10 a.m.	--	Est 17	3.2	--
State Road 57 below South Fk Patoka near Oakland City	9:40 a.m.	--	Est 17	1.9	--
Downstream 100 yards from State Road 61 at Winslow	10:30 a.m.	--	Est 17	4.9	--
State Road 257 below Rock Creek	11:00 a.m.	--	Est 17	1.3	--
U. S. 231 between Jasper and Huntingburg	11:45 a.m.	--	Est 17	1.2	--
State Road 545 at Dubois	12:30 p.m.	--	Est 17	2.7	--
State Road 65 near Princeton	2:00 p.m.	30	16	3.2	2.2
State Road 57 below South Fk Patoka near Oakland City	2:45 p.m.	31.5	17	1.8	3.1
Downstream 100 yards from State Road 61 at Winslow	3:20 p.m.	33	18	5.4	4.5
State Road 257 below Rock Creek	4:00 p.m.	31	17.5	1.5	4.9
U. S. 231 between Jasper and Huntingburg	4:45 p.m.	31	17.5	3.4	17.4
State Road 545 at Dubois	5:35 p.m.	28	18.5	3.5	4.4
	Oct. 24, 1963				
State Road 65 near Princeton	8:30 a.m.	17	16	2.5	--
State Road 57 below South Fk Patoka	9:15 a.m.	20	16	2.1	--
Downstream 100 yards from State Road 61 at Winslow	9:45 a.m.	20.5	16	5.0	--
State Road 257 below Rock Creek	10:20 a.m.	22.5	16	0.7	--
U. S. 231 between Jasper and Huntingburg	11:00 a.m.	24.5	17	1.6	--
State Road 545 at Dubois	11:45 a.m.	24	17	1.9	--

Pertinent Data

The proposed Patoka Reservoir would have a miminum pool with a capacity of 13,200 acre-feet and a conservation pool that could store a total of 181,000 acre-feet of water. These storage volumes would be achieved at elevations 506 feet and 536 feet for low and conservation pools respectively.

According to the Indiana Flood Control and Water Resources Commission,[4] the above storage and elevations would give a safe yield of 125 cfs at Jasper and 175 cfs at Princeton.

Even though a safe yield may be determined, the distance from the project site to Jasper makes the releases from the proposed reservoir subject to losses such as water use and irrigation in the valley floor as well as the increased natural losses normal to supplemented streamflow.

IV. DESCRIPTION OF STUDY AREA

Location and Boundaries

The Patoka River Basin is located in the southwestern part of Indiana and lies generally in an east-west direction (See Figure I). Patoka River drains parts of eight counties: Crawford, Dubois, Gibson, Martin, Orange, Pike, Spencer, and Warrick. This 867 square mile basin is long and narrow. It varies in width from about a mile at the river mouth to about 15 miles at a point about 25 miles east. For the next 35 miles eastward, the basin averages about 15 miles in width. For the last 18 miles of basin length, the average width is about 10 miles.

Geography

Patoka River meanders about 164 miles generally westward from its source in Orange County to its mouth which is at a point on the Wabash River across from Mt. Carmel, Illinois, and about a mile downstream from the mouth of White River. There are no large tributaries to Patoka River, the largest being Huntley Creek with a drainage area of 81.7 square miles. This stream has approximately the same features as to runoff and velocities as the main stem in its upper reaches.

The topography around the perimeter of the basin is rolling to moderately steep. Near the river mouth in the Wabash valley plains, the topography is flat or gently rolling. The stream has a fall of about 480 feet of which almost three quarters is in the upper third of the

basin. This gradient feature results in high velocities in the headwaters and comparatively sluggish flow in the greater length of the main stem.

The above factors contribute to rapid runoff following periods of precipitation and to quite low stream flows annually.

Climate

The Patoka Basin is situated in a region that experiences comparatively moderate climate. The mean annual temperature[5] is about 56.5° and varies from a monthly mean high of about 91°, a monthly mean low of about 25.0° and a maximum temperature of 113° to a minimum 26° below zero.

Precipitation in the basin is fairly well distributed throughout the year even though a wider departure from normal occurs during the first six months of the year. The mean annual precipitation[5] is 42.97 inches at Princeton, 48.59 inches at Huntingburg, and 44.12 inches at Paoli, somewhat north of the eastern end of the basin. The monthly totals have varied from a maximum of 17.83 inches to only a trace in each of two different months.

Principal Communities and Industries

The principal communities affecting or affected by the Patoka River are Jasper, Huntingburg, Winslow, Oakland City, and Princeton. Winslow and Oakland City are primarily mining towns although Oakland City has a plastics plant of considerable importance to the community. Jasper and Huntingburg

are primarily wooden furniture centers but have some packing and produce plants. Princeton has a variety of small industries producing such items as electronic equipment, oil field equipment, rubber products, castings, and meat and dairy products.

V. ECONOMY

Present Economy

Area Included

The area of influence of the proposed Patoka Reservoir lies in the southwestern part of Indiana. The three counties of Pike, Gibson, and Dubois have been studied as representing the immediate extent of the area of influence of the reservoir.

Agriculture

Agriculture stands out in importance to the economy of the basin. In 1960, 20.6 percent of all employment or 5,521 were employed in farming. During the twenty-year period, 1939-1959, the number of farms decreased from 5,749 to 4,024. Land resources utilized in agricultural production increased by 61,843 acres, and value of output increased $18,540,000.*

Agricultural Trends in the
Three-County Area
1939-1959

	Farms	Acres Harvested	Farm Products Sold *
1939	5,749	295,000	$ 10,080,000
1959	4,024	316,843	$ 28,620,000

* Expressed in constant 1959 dollars

Mineral Industries

The extraction of mineral resources in the three-county area included coal, petroleum, clay, sand, and gravel. The total value of mineral activity for the years as close to 1960 as could be obtained was $23,412,000 as shown in Table 4. The value of output represents approximately 11 percent of the Indiana state total. Mining employment of 1,221 comprised 7.5 percent of all employment in the state of Indiana in 1960. The 1,221 employment figure represents a decline of 43.8 percent from the 1950 employment figure of 2,174.

Table 4

Summary of Mineral Production in Study Area *

Location	Minerals	Value
Dubois County (1960)	Coal, clay, sand, gravel	$ 125,000
Gibson County (1959)	Coal, sand, gravel	2,300,000
Pike County (1960)	Coal	7,400,000
	Sub Total	$ 9,825,000
Dubois County (1958)	Crude petroleum, natural gas	------------
Gibson County (1958)	Crude petroleum, natural gas	9,961,000
Pike County (1958)	Crude petroleum, natural gas	3,626,000
	Sub Total	$ 13,587,000
	Grand Total	$ 23,412,000

* Sources: Minerals Yearbook 1960, Volume III, Area Reports
Census of Mineral Industries 1958, Volume II, Area Statistics

Manufacturing

Manufacturing accounted for 23.6 percent of the labor force (6,306) in 1950, but in 1960 accounted for 26.2 percent of the labor force (7,022) netting an increase of more than 700 employees. Value added by manufacture approximated $32,900,000 in 1958, an increase of $6,100,000 over the value added in 1954 in constant 1958 dollars.

Table 5 shows the distribution of manufacturing plants according to industry class and size as measured by employment. In 1958 there were 138 plants engaged in the manufacture of products.* Although small in scale of operation, the industrial structure of the basin is well diversified. With the exception of tobacco products, paper, leather, and textile mill products, all categories of manufacturing are found in the three-county area. The leading type of manufacturing activity measured by both employment (See Table 7) and number of plants are lumber and wood products, and furniture and fixtures. As measured by number of employees, electrical machinery and food processing are next in importance.

Table 6 summarizes the manufacturing plant information from the 1958 Census of Manufactures in each county and indicates the possible high water intake plants and potential waste producers. All plants are included which had over 100 employees and whose 4-digit Standard Industrial Classification code industry is included in the listing of industries with an intake of over 20 million gallons per year in the Industrial

* U.S. Census of Manufactures

Table 5

Number and Employment Size of Manufacturing Plants
Patoka River Basin
1958

Type	EMPLOYEES (1-19)	(20-99)	(100-249)	(250-over)	Total
Food & Kindred Products	21	2	2	1	26
Tobacco Products					
Textile Mill Products					
Apparel & Related Products		1			1
Lumber & Wood Products	23	6	1		30
Furniture & Fixtures	6	18	7	2	33
Paper & Allied Products					
Printing & Publishing	12	2			14
Chemicals & Allied Products	1				1
Petroleum & Coal		1			1
Rubber & Plastic		2			2
Leather Products					
Stone, Clay, Glass	5	3			8
Primary Metals	1	1			2
Fabricated Metals	4	1			5
Non-Electric Machinery	3	1			4
Electrical Machinery			1	1	2
Transportation Equipment	1	2			3
Instruments & Related Products	1				1
Miscellaneous			1	4	5
Total	78	40	12	8	138

Table 6

Summary of Manufacturing Plants by Counties, 1958

10 Plants
None over 19 Employees

PIKE COUNTY — Potential Waste Producers

SIC* Code	Industry Description	Number Plants	Employment Range	National Average Water Intake per Employee per Year Gallons
2011	Meat Packing	1	1-19	

28 Plants
4 over 100 Employees

GIBSON COUNTY — High Water Intake Plants

SIC* Code	Industry Description	Number Plants	Employment Range	National Average Water Intake per Employee per Year Gallons
2011	Meat Packing	1	500-999	582,000
2711	Petroleum Refining	1	50-99	9,727,000
3069	Fabricated Rubber Prdts.	1	50-99	496,000
3613	Switch Gear, Switch Boards	1	500-999	244,000
3621	Motors & Generators	1	100-249	127,000
	Potential Waste Producers			
2011	Meat Packing Plants	4	1-19	

96 Plants
12 over 100 Employees

DUBOIS COUNTY — High Water Intake Plants

SIC* Code	Industry Description	Number Plants	Employment Range	National Average Water Intake per Employee per Year Gallons
2015	Poultry Dressing Plants	1	100-249	422,000
2026	Fluid Milk	1	100-249	356,000
2432	Veneer & Plywood	1	100-249	727,000
2432	Veneer & Plywood	1	50-99	727,000
2511	Wood Furniture (Not Uphol.)	1	100-249	78,000
2511	Wood Furniture (Not Uphol.)	2	250-499	78,000
3273	Ready Mix Concrete	1	1-19	1,386,000
3273	Ready Mix Concrete	1	20-49	1,386,000
3069	Fab. Rubber Products	1	50-99	496
	Potential Waste Producers			
2011	Meat Packing Plants	4	1-19	
2015	Poultry Dressing	1	1-19	

* Standard Industrial Classification

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WABASH RIVER BASIN COMPREHENSIVE STUDY COVERING RESERVOIR SITES--ETC(U)

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Water Use Survey, 1958 Census of Manufactures. Plants with fewer than 100 employees are listed only if the industrial water intake per employee for their SIC category was very high as shown in the Table.

Non-Commodity Industries

With about 43 percent of its employment in non-commodity industries, the study area averaged about 5 percent less than in this category for the state. Trade with 15.4 percent and personal services with 13.6 percent represented the largest part of the employment in this category. Non-commodity employment and manufacturing employment increased by about the same percentage (3+ percent) between 1950 and 1960.

Transportation

There is no river transportation in the basin. Furthermore, no commercial airline services are available. However, four railways (Ferdinand, Southern, New York Central, and C&E) pass through or cross part of the basin. Two major state highways (U.S. 231 and Indiana 57) run north-south through the basin and there are a number of good paved roads affording convenient and fast transportation. Freight transportation is made available via the presence of several interstate and intrastate trucking lines.

Income

The per capita cash income in the study area was $1,438 * in 1960. This compares to the state average of $1,832 and $1,849 for the Nation.

* 1960 Census of Population

Because of the rural nature of this area and the larger portion of income coming directly from farm products, the real income in the study area may not be as much lower than the state as the figures might indicate.

Population

Total population in the three-county area rose from 66,116 to 70,333 between 1930 and 1940. In 1950 the area's population had decreased slightly to 69,500, but in 1960 registered a total population of 70,209. In 1960 the three counties comprised 1.49 percent of Indiana's population. The average annual percentage change in population has been greater for both the Nation and the state compared to the study area.

In 1960 the urban sector of the population amounted to 24,738. This number represented 35.3 percent of the total population and is concentrated in the five cities of Jasper, Princeton, Huntingburg, Oakland, and Petersburg. Rural population, farm and non-farm, was 45,460 in 1960 changing very little from the rural population of 45,982 in 1950.

Projected Economy

Projections of the economy of the Patoka River Basin were derived from determining historical trend relationships between the study area and the state, and projecting those relationships using as a basis projections for the state prepared by the National Planning Association, Washington, D. C. Past trends were modified in accordance with judgment based on additional information. These projections are of a preliminary nature and may be modified, if necessary, upon receipt of the Arthur D. Little Company, Inc. Economic Base Study report for the Ohio River Basin.

Employment Projections

Table 7 lists projections for employment to 1976. It is expected that non-commodity sectors will continue to experience expansion in employment, while agriculture and mining will decrease their employment. Manufacturing employment is expected to approximate 9,800 by 1976 with furniture, wood, and lumber products continuing to be the heaviest in employment, and the electrical machinery industry undergoing the most rapid growth in employment.

Population Projections

Table 8 gives population projections to 1976 and 2010. The study area is projected to lag behind the rate of population growth expected for the state and the Nation. (See Figure II). From its population of 70,209 in 1960, the study area is expected to number a population of 90,000 in 1976 and 150,000 in 2010. Projections for the five cities in the basin reflect the anticipated growth of current urbanized areas.

Table 7

Patoka River Basin
Historical and Projected Employment

	1950	% of C.E.[b]	1960	% of C.E.[b]	1976	% of C.E.[b]
Total Civilian Employment	26,670	100.0	27,338	100.0	34,790	100.0
Agriculture	6,618	24.8	5,521	20.2	4,140	11.9
Mining	2,174	8.2	1,221	4.5	1,160	3.3
Construction	1,184	4.4	1,373	5.0	2,240	6.4
Non-Commodity Industries	10,338	39.0	11,702	42.8	17,450	50.2
Transportation[a]	1,746	6.5	1,388	5.1	1,850	5.3
Trade	4,137	15.5	4,221	15.4	6,100	17.5
Finance	360	1.4	502	1.8	800	2.3
Services	2,805	10.6	3,709	13.[illegible]	6,100	17.5
Government	1,340	5.0	1,882	6.9	2,600	7.6
Manufacturing	6,306	23.6	7,521	27.5	9,800	28.2
Durables	4,982	18.7	5,592	20.4	7,790	22.4
Furniture-Wood-Lumber	2,815		3,279		3,600	
Primary Metals	18		79		110	
Fabricated Metals	68		166		270	
Non-Electric Machinery	841		192		250	
Electric Machinery	657		1,505		2,900	
Transportation Equipment	189		140		250	
Other Durables	394		231		310	
Non-Durables	1,324	4.9	1,929	7.1	2,010	5.8
Food	912		1,210		1,300	
Textiles	8		9		10	
Apparels	142		119		70	
Printing	135		203		250	
Chemicals	70		48		200	
Other Non-Durables	57		340		180	

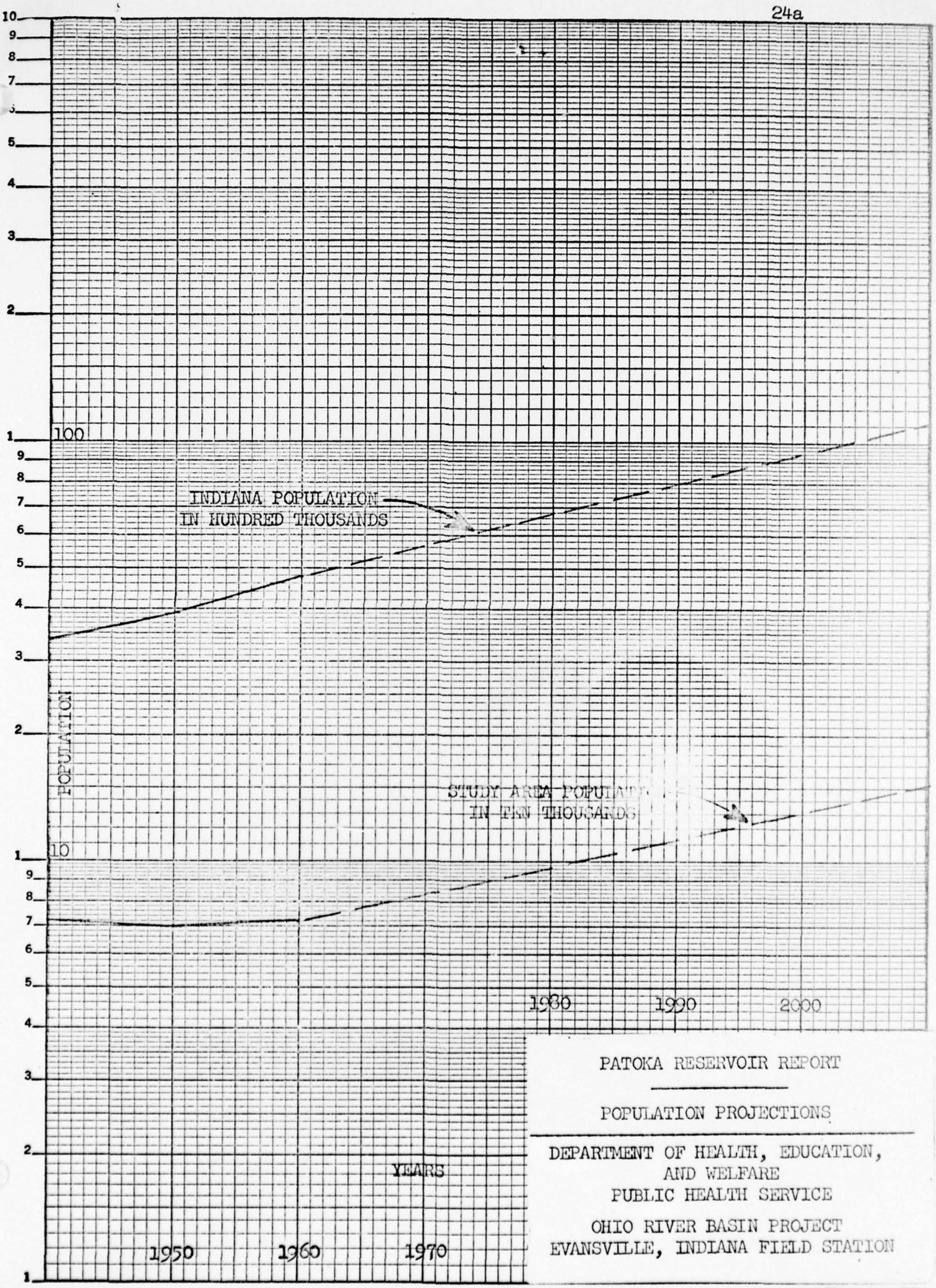
[a] Includes Communications and Utilities

[b] Civilian Employment

Table 8

Patoka River Basin
Historical and Projected Population

	1950	1960	1976	2010
Study Area (Pike, Gibson, Dubois Counties)	69,500	70,209	90,000	150,000
Dubois County				
Bainbridge Township (Incl. Jasper)	7,524	9,564	15,000	25,000
Jasper Only	5,215	6,737	11,000	18,000
Patoka Township (Incl. Huntingburg)	5,222	5,547	7,200	12,000
Huntingburg Only	4,056	4,146	6,000	9,000
Gibson County				
Patoka Township (Incl. Princeton)	11,189	11,135	14,000	20,000
Princeton Only	7,673	7,900	9,500	14,000
Columbia Township (Incl. Oakland)	4,766	4,158	5,300	8,500
Oakland Only	3,539	3,016	4,100	6,600
Pike County				
Washington Township (Incl. Petersburg)	5,128	4,490	5,600	8,800
Petersburg	3,035	2,939	4,000	6,500



PATOKA RESERVOIR REPORT

POPULATION PROJECTIONS

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

OHIO RIVER BASIN PROJECT
EVANSVILLE, INDIANA FIELD STATION

Figure II

VI. WATER REQUIREMENTS

As the population increases and industrial growth occurs, greater demands will be made for water. Hence, the growth projected in the preceding section supports projections of increased water needs.

Past and Present Water Use

Municipal

Water use by the municipalities in the basin or within its influence is given in Table 9.

Industrial

Any significant industrial needs of water in the basin are served from municipal supplies. As there are limitations in quantity and quality, industries that would require appreciable quantities of water have not been attracted to the area.

Existing Sources

At present, local impoundments on tributary streams are utilized for water supply for Ferdinand, Huntingburg, Jasper, and Oakland City. Wells are the source of supply for Francisco, Patoka, and Princeton. Winslow uses water directly from the Patoka River and Jasper uses river water augmented during low flow from its Beaver Creek Reservoir.

Ground water[7] is not a source of large quantities of water in the Patoka River Basin. This is especially true in the upper three-fourths of the basin where bedrocks of Pennsylvanian and Mississippian ages are

Table 9

Municipal Water Systems[6]
Patoka River Basin

Municipality	1960 Population	Estimated Population Served	Source	Treatment	Design Capacity (mgd)	Average (mgd)	Demand (gpcd)
Ferdinand	1,427	1,900	Two Impoundments on Unnamed Tributaries of Hunley Creek	Filtration, Chlorination	0.20	0.099	52
Francisco	565	-	Wells	Chlorination	0.09	0.030	53
Huntingburg	4,146	-	Impoundments on Unnamed Tributaries	Filtration, Chlorination	2.18	0.457	110
Jasper	6,737	-	Patoka River Impoundment	Filtration, Chlorination	2.16	0.91	135
Oakland City	3,016	-	Two Impoundments on Unnamed Tributaries of S.Fork, Patoka R.	Filtration, Chlorination	1.30	0.238	77
Patoka	579	-	Wells	Chlorination	0.20	0.035	63
Princeton	7,906	-	Wells	Softening, Filtration, Chlorination	2.00	0.898	114
			Patoka River	(Emergency)			
Winslow*	1,089	-	Patoka River	Filtration Chlorination	0.29 0.29*	0.074	68

*New plant under contract. To be built with aid of federal grant.

prevalent. These bedrocks, consisting of sandstone, shale, and limestone, are sources of small supplies of water because of their small permeability and lack of secondary openings. Only in the lower part of the basin below Princeton may suitable supplies of ground water be found in the sand and gravel of the Pleistacene age.

No determination has been made of the maximum dependable draft which can be developed for communities using well fields. Neither has the safe yield been determined for Oakland City's impoundment. The safe yields for impoundments at other cities are as follows: Jasper, 3.0 mgd; Ferdinand, 0.219 mgd; and Huntingburg, 0.65 mgd. The discharge of the waste treatment plants at Jasper and Huntingburg will provide the minimum quantity of flow needed for a water supply at Winslow. It is pointed out that during low flow periods, the raw water supply at Winslow will consist of treated sewage. It is understood that water supply for Francisco[8] is inadequate. Present supplies for Huntingburg, Oakland City, and Jasper are not expected to be adequate for anticipated growth beyond 1980.

The Jasper water supply is taken from Patoka River. An impoundment on Beaver Creek, about seven miles upstream, is used to supplement river discharge during the periods of inadequate flow experienced nearly every year.

Huntingburg water is supplied from an impoundment in the headwaters of a small unnamed tributary to Patoka River. The current rate of use does not show the two significant decreases in water usage in the past decade. Due to the loss of a water using industry and more recently to a sewer tax imposed and based upon water consumption, per capita water use declined. In each instance, the rates of water use soon recovered to that experienced prior to the cutback. At present, the consumption is approaching the safe yield limit of the impoundment. Huntingburg has contemplated the use of Patoka River as a source of supply; but due to the inadequate flows and unsuitable water quality, has been compelled to consider enlargement of its present impoundment. Huntingburg would pump water from the Patoka River if it could be assured of an adequate quantity of good quality water by the development of an upstream reservoir.

Downstream from Huntingburg, the town of Winslow depends upon Patoka River flow. This source has often proved to be of unsuitable quality.

To the west and downstream from Winslow, Oakland City considers the Patoka River to be an emergency source of supply even though the quality is not entirely satisfactory because of acid mine wastes and the combined waste loading from upstream.

The most downstream community along the Patoka River is Princeton which is situated on the divide between Patoka River and Pigeon Creek. Prior to 1941, Princeton's water supply source was from the Patoka River.

Since that time, wells have been used with the Patoka River intake kept as an emergency source. The change in source of supply was prompted by the presence of excessive amounts of acid mine wastes.

Ranges in water quality of supplies for the communities in the Patoka River Basin are given in Table 10.[9]

Additional Water Needs

Municipal

It is expected that water demand for communities will vary with the economy of the area and with the availability of water. Table 11 shows estimates for future per capita and municipal use. This tabulation gives the best estimate of water uses that can be made at this time. If more detailed and more reliable data become available, a revision of estimates for future municipal use may become necessary. Light industrial uses are expected to be served from the municipal supply. Table 11 includes such anticipated use.

Industrial

As indicated previously, industrial needs for water presently are satisfied from municipal supplies. It is not anticipated that the source of supply for the types of industries presently in Jasper will change. If any industries using large volumes of water are attracted to the area when water becomes plentiful, water use would increase at a rate greater than that computed for municipal needs in this report; however, a small

Table 10

Quality of Municipal Water Supplies (Raw Water)[9]
Patoka River Basin

Physical and Chemical Characteristics	Ferdinand	Francisco	Huntingburg	Jasper	Oakland City	Patoka	Princeton	Winslow
pH	7.5	7.5	7.7	7.4	8.3	7.8	7.6	7.4
Color	5	0-5	5-25	5-20	5	5-10	0-10	5-80
Turbidity	0.1-30	3-60	0-40	15-100	2-5	0.5-30	0.3-40	50-400
Hardness as $CaCO_3$	40-100	190-380	45-85	95	30-55	230-310	240-320	85-110
Calcium as Ca		35-75				55-65	70-75	
Magnesium as Mg		25-45				20-25	20-25	
Sodium as Na		35-110				25-30	10	
Potassium as K		1-3				1	2	
Iron as Fe	0.05-0.8	0.1-8.0	0.05-0.7	0.4-1.6	0.04-0.2	0.8-5.0	0.5-5.8	1.2-3.3
Manganese as Mn		0.05		0.2-0.7		0.05	0.05-0.1	0.8
Alkalinity (Total) as $CaCO_3$	20-100	340-470	25-50	70-80	10-40	270-340	200-340	35
Chlorides as Cl	4	6-8	3			1-5	5-10	
Sulphates as SO_4		0-20				0-2	25-50	
Nitrates as N	1-	2-				2-	1-	
Flourides as F	0.2	0.1-0.8	0.2	0-0.3		0.1-0.4	0-0.1	

Table 11

Future Municipal Water Supply Requirements
Patoka River Basin

Municipality	Population			Per Capita Use GPCD			Total Municipal Use MGD		
	1960	1976	2010	1960	1976	2010	1960	1976	2010
Birdseye	366	400	500	---	125	150		0.05	0.075
Jasper (Bainbridge T.)	6,737	11,000	18,000	135	175	225	0.91	1.92	4.05
(Including Jasper)	9,564	15,000	25,000	---	175	225	Unk.	2.62	5.62
Huntingburg	4,146	6,000	9,000	110	150	175	0.46	0.90	1.58
Winslow	1,089	1,200	1,500	68	100	150	0.07	0.12	0.22
Oakland City	3,016	4,100	6,600	77	125	150	0.23	0.51	0.99
Princeton	7,906	9,500	14,000	114	150	175	0.90	1.42	2.45
Patoka	576	630	800	63	100	150	0.04	0.06	0.12

amount is forecast for self-supplied industries. A more immediate industrial use for water is for cooling of the thermal power plant at Jasper. Present plant capacity is sufficient for a limited period of time. If Patoka River water were available in sufficient quantity, Jasper would use that water instead of constructing cooling towers when expanding the present plant facilities. The amount of water needed to replace the cooling towers, according to estimates, is about 15 mgd. If the cooling water from the power plant were discharged into the river below the water supply intake, the loss of dissolved oxygen due to increased temperature would probably not exceed 0.5 mg/l in the total estimated needed flow of 75 cfs at Jasper.

The industrial needs for Jasper and Huntingburg are listed in Table 12. Water for self-supplied industries has been provided for within the tabulation (Table 12). This tabulation, like that for municipal supply, is based upon the best estimates that can be made at this time. Revision of the figures in Table 12 may be required if further data become available.

The estimated municipal and industrial quantities shown as needed by the year 2010 (31.6 cfs) are well under the total available discharge of 125 cfs which could be provided at Jasper.

Table 12

Industrial Water Requirements
Patoka River Basin

Community	1960 (mgd)	1976 (mgd)	2010 (mgd)
Jasper			
Thermal Power Plant			
Cooling Water	0	15.0	15.0
Industrial Need	0	1.3	2.8
Huntingburg			
Industrial Need	0	.4	.8
Total Industrial Need	0	16.7	18.6

Water Quality Objectives

The water quality objectives used as a basis for determination of need for storage for regulation of streamflow for purpose of water quality control are all related to the downstream land uses and instream uses of the waters. Where proper quality is not maintained, possible economic benefits of its use may be foregone and the public health may be endangered.

The objectives used in evaluating quality conditions in the Patoka River have been based mainly on the use of Patoka River waters as a source of raw water supply for communities, for preservation of aquatic life, and for present and prospective general recreational use.

The Manual of Recommended Water Sanitation Practice of the Public Health Service has been used as a guide to acceptable raw water quality and is used to select quality objectives for raw water sources for municipal water supplies.

With respect to the coliform bacterial content of raw waters, if coliform objectives are not met at downstream water intakes, the cheapest solution is considered to be to chlorinate effluent from sewage treatment plants. However, all wastes cannot be collected such as street washings and storm water overflows.

Waters acceptable for treatment, in addition to meeting bacterial requirements, should not contain any toxic, taste-producing, or otherwise harmful substances, or organisms not readily or completely removable by ordinary water treatment. Raw waters should be free of excessive amounts

of acid, microscopic organisms, and organic matters causing any interference with normal operation and efficiency of water treatment processes.

Attention is invited to the location of the largest city in the basin as being eight miles upstream from the possible future water intake of the third largest city in the basin. The time of flow would be approximately eight hours and under drought conditions, the flow would be mainly treated sewage, and in the year 2010, this quantity is estimated to be 13 cfs. The treated sewage must be diluted with a water of good quality such as could be released from the proposed Patoka Reservoir. In the next paragraph, it is shown that the computed flows would achieve 5 mg/l of dissolved oxygen at the critical point. It is believed that the same quantity needed to achieve 5 mg/l of dissolved oxygen in the stream would adequately dilute the treated wastes and provide waters acceptable as a raw water supply for Huntingburg.

In setting water quality objectives for streams for the protection of aquatic life, mere survival is not enough. The minimum level selected should be suitable for the continuous maintenance of satisfactory fish life and fish food organisms. Objectives are therefore based upon the environmental requirements of the fish species present in the river. On the basis of studies by the Public Health Service in the Cincinnati area, it was concluded that for a well-rounded, warm water fish population dissolved oxygen concentrations should not be below 5 mg/l for more than 8 hours of any 24-hour period. Based on these considerations, a dissolved

oxygen objective of 5 mg/l has been established for the Patoka River to preserve desirable aquatic life and to ensure present and future recreational use of the river. The flows shown as needed are those required to achieve 5 mg/l at the critical point below Huntingburg in the year 2010.

The State of Indiana has a minimum requirement of 4.0 mg/l of dissolved oxygen and an objective of 5 mg/l of dissolved oxygen. Therefore, the objectives of the State of Indiana would be achieved after adequate treatment of wastes in the upper two-thirds of the Patoka River Basin.

Water Quality Control

From an inspection of Table 13, it can be seen that all municipal wastes are or will be adequately treated. Adequate treatment at the present time amounts to 85 percent removal of the 5-day biochemical oxygen demand. Quantities of water required for water quality control have been computed on the premise that such treatment will continue to be provided. A list of treatment plants presently in use in the basin is given in Table 13.[10]

The most critical reach of Patoka River is between Jasper and the mouth of Hunley Creek from which Huntingburg's wastes are introduced into the river. When Huntingburg's present water supply reaches its limit, the obvious source of water would be Patoka River if proper

Table 13

Municipal Waste Treatment[10]
Patoka River Basin

Municipality	1960 Population	Population Served	Design Flow (mgd)	Treatment	Remarks
Birdseye	366	--	--	None	No sewer system.
Jasper*	6737	6200	1.00	Sedimentation Activated Sludge	
Ferdinand	1427	1427	--	--	Combined sewer system. Preliminary report being prepared.
Huntingburg	4146	4146	0.675	Sedimentation Trickling Filter	
Winslow	1089	1089	--	None	Combined sewer system. Preliminary engineering report prepared for treatment plant.
Oakland City	3016	3016	0.20	Sedimentation Trickling Filter	
Princeton	7906	7300	1.00	Sedimentation Trickling Filter	Effluent diverted to Pigeon Creek.
Patoka	576	--	--	--	No sewer system.

*Jasper is currently extending its sewerage system.

quality control is maintained on that stream. Inasmuch as Jasper's outfall is less than eight miles from the point where Huntingburg would be expected to obtain its water, natural stream assimilative capacity would not have time to adequately recover to a quality suitable as a source of supply for the community of Huntingburg.

The quantity that would be required to achieve a dissolved oxygen content of 5 mg/l at the critical point would also provide reasonable dilution of the treated Jasper wastes so as to make the river water suitable as a source of raw water for municipal use at Huntingburg.

At Hunley Creek, the Huntingburg sewage plant effluent adds its loading to that of Jasper. Even so, this portion of the river downstream from Huntingburg gives somewhat less cause for concern than above the potential Huntingburg water intake site because of the greater distance to Winslow. This community with only a pumping pool in Patoka River must depend upon that stream for its water supply. For that reason, suitable quality maintenance below Huntingburg is highly desirable.

The water quality control quantity needed below Jasper to provide 5 mg/l at the critical point would also be adequate to receive and assimilate the adequately treated wastes from Huntingburg. The resulting quality at Winslow would be acceptable as a source of raw water supply for municipal use.

The water required to afford suitable quality control is indicated in Table 14.

Table 14

Water Quality Control Needs in MGD
Patoka River Basin

Municipality	1960	1976	2010
Jasper (Bainbridge T.)			
To Receive Municipal Wastes	4.5	13.1	28.1
To Receive Industrial Wastes	0	6.5	14.0
Cooling*	0	1.5	1.5
	4.5	21.1	43.6
Huntingburg**			
To Receive Municipal Wastes	2.3	4.5	7.9
To Receive Industrial Wastes	0	2.0	4.0
	2.3	6.5	11.9
Total requirement for water quality control**	4.5	21.1	43.6

*Additional flow needed to compensate for loss in assimilative ability of stream as a result of temperature increase.

**If water quality control requirements for the Patoka River below Jasper are met, sufficient flow will be available to provide suitable quality below the mouth of Hunley Creek into which Huntingburg's wastes are discharged.

As Oakland City's supply becomes inadequate due to increased needs for municipal and industrial water supply, the city would look to the Patoka River as the most probable source of raw water to supplement its present supply. While Oakland City is located downstream from Winslow, if the adequately treated wastes from Winslow would be received by the water quality control flows shown as needed below Jasper, then an adequate quality of raw water would be expected at the Oakland City intake.

Princeton, Indiana depends upon the Patoka River as an emergency water supply. Princeton is located about 13 miles downstream from Oakland City. The present water quality of the Patoka River at Princeton's intake is excessively degraded by mine acid wastes, oil field brines, and excessive hardness. An indication of the Patoka River quality of water is shown in Table 2. The extent and nature of the pollution problems and the methods used by local operators to abate pollution caused by oil well and coal field operations have not been studied due to time limitations. Until a determination can be made as to whether adequate treatment or other methods of controlling waste at the source is practiced in the above described problem area of the Patoka River Basin, no recommendation for storage for regulation of streamflow for purpose of quality control for the oil field and acid mine problems will be provided. The full extent of the oil field and acid mine problems, present and planned methods of pollution control, and the need for and value of storage

for regulation of streamflow to receive residual wastes after adequate treatment from oil field and coal mine operations will be described in a later report. Under existing conditions, it is probable that a flow of 125 to 200 cfs would be required to provide a quality of water suitable as a source of raw water supply at Princeton's intake and for an environment in which aquatic life could be sustained.

The flows previously discussed as needed at and below Jasper would also improve the present quality of water in the Patoka River below Jasper, even though the quality at Princeton might not be of as high a quality as desired. These flows would also improve the quality of water in the Wabash River below Mt. Carmel, Illinois, and in the Ohio River downstream from the Wabash River.

Table 15 gives a summary of the needs for water supply and for water quality control in the basin. The needs shown on Table 15 are for the summer season at Jasper. An indication of the seasonal variation in these water quality control needs is given in Table 16.

Plan for Supplying Future Requirements

Ultimate Capability and Desirability of Present Sources

Some communities within the Patoka River Basin are not likely to become direct users of water from the Patoka River. Others would be expected to take advantage of any increase in flow and improvement of quality in the Patoka River. The communities which should be expected to utilize the proposed Patoka Reservoir as a source of supply are

Table 15

Summary of Needs
Patoka River Basin

COMMUNITY	1960 (mgd)	1976 (mgd)	2010 (mgd)	Draft on Storage Acre Feet 1976	Draft on Storage Acre Feet 2010
Jasper (Bainbridge T.)					
Municipal Water Required	0.91	2.62	5.62		
Design Flow + Storage	3.00	3.00	3.00		
Additional Municipal Needs	----	----	2.62		
Industrial Water Required	0	1.30	2.80		
Total Municipal and Industrial Water Needs	0	1.30	5.42	600	2,800
Cooling Water Required	0	15.00	15.00	9,400	9,400
Total Municipal, Industrial and Cooling Water Needs	0	16.30	20.42	10,000	12,200
Water Required for Quality Control	4.50	21.10	43.60		
Design Flow (Seven day once in ten years)	0	0	0		
Total Water Quality Control Needs	4.50	21.10	43.60	13,400	37,600
Total Water Needed in mgd*	4.5	22.4	49.0	14,000	40,400
Princeton**					
Water Required for Quality Control (in cfs)	125 to 200	125 to 200	125 to 200		

*This item does not include the 15 mgd Cooling Water Requirement as such. The 15 mgd is available for and included in Total Water Quality Control Needs.

**See discussions on pages 51-53.

Table 16

Seasonal Variation in Water Quality Control Needs at Jasper Patoka River Basin

Season	Seasonal Need in CFS	
	1976	2010
Winter	11	23
Spring	19	39
Summer	33	68
Fall	21	42

Birdseye, Jasper, Huntingburg, Winslow, Oakland City, and possibly Princeton. The other communities such as Ferdinand, Francisco, and Patoka are not so likely to consider the Patoka as a source. Time available for this preliminary appraisal does not permit a study to determine the most feasible source for these communities and because their water consumption would not be large, they would have little effect upon the economics of the proposed Patoka Reservoir.

Birdseye is presently planning for a water supply. An impoundment will be required to furnish the water for the community.

Jasper's present reservoir has sufficient capacity to provide a safe yield of 3.0 mgd. This quantity of water is expected to satisfy Jasper's municipal requirements until about 1980. However, sufficient water is not available to provide suitable water quality control downstream from Jasper. Due to low flows, the quality of the river water downstream from Jasper is in a degraded condition during parts of two or more months every year.

Huntingburg is less certain of its safe yield than Jasper. Although the community did not run out of water during the 1953-54 drought, the supply did become dangerously short. At that time, the capacity of the reservoir was determined to be 477 million gallons. Now, because of siltation, the capacity is believed to be less. It appears that Huntingburg will be in need of additional water supply by 1980.

Winslow is assured of a water supply as long as Jasper and Huntingburg have a supply. Because of the discharge of sewage treatment plant effluent from those cities, the quantity will be ample for Winslow but the flow will be mainly treated sewage during periods of low flow.

Oakland City has sufficient water for present needs. The Patoka River is considered an emergency supply but if it were needed, the quality should be expected to be similar to that of Winslow, and therefore require extensive treatment.

Princeton depends upon wells for its supply. Three of these wells are of the gravel-packed type along the river.

Alternate New Sources

The most practical new source of water supply for the communities along the Patoka River would be one multi-purpose water supply reservoir with capacity for municipal and industrial water supply needs and for storage for regulation of streamflow for the purpose of water quality control. The most suitable location for such a reservoir would be upstream from Jasper. The next most practical alternate solution would be municipal and industrial water supply impoundments for each community and one single purpose reservoir with storage for regulation of streamflow for the purpose of water quality control located upstream from Jasper, Indiana. Because some communities already have two dams, this alternative is a piecemeal approach and should be considered only as a last resort.

Ground water has previously been considered and it has been determined that ground water is not available as a source of large quantities of water, especially in the upper three-fourths of the Patoka Basin.

VII. BENEFITS OF STORAGE

Introduction

Due to time limitations, this study consisted of a preliminary appraisal of needs for water supply and for water quality control. It has been determined that certain minimum needs exist for water supply and for water quality control. Greater needs are possible. These municipal water supply needs will be met as the demand develops in each community. Probably no local provision would be made for storage for regulation of streamflow for the purpose of water quality control. A more efficient method would be to plan for all the needs and to supply them with a single multi-purpose project.

Alternate Plan

An alternate plan could be used to provide water for municipal and industrial water supply in place of the proposed multi-purpose Patoka Reservoir. This plan would cause the individual communities to provide their own separate water supplies. Water for quality control purposes could be stored most economically from a single purpose reservoir upstream from Jasper, but it is believed that such a structure would not be built by these communities.

The above plan would require single purpose reservoirs for each of several communities. Birdseye, which is situated upstream from the proposed Patoka River dam site, would need an impoundment for its proposed water supply.

Jasper will need an additional single purpose storage reservoir approximately equal in size to its present impoundment or about 2800 acre-feet. This added storage capacity will be needed by about 1980.

No provision is made for cooling water for Jasper's steam generator plant as cooling towers would be substituted under this alternate plan.

Huntingburg also would be expected to enlarge its present storage capacity possibly before 1976. An additional single purpose reservoir with a capacity of about 1500 acre-feet should provide a safe yield until 2010.

Winslow proposes to continue the use of Patoka River water for its supply. This community is situated on the river so that no pipeline of appreciable length is necessary.

It is anticipated that Oakland City will need additional water by 1976. Under this alternate plan, an additional impoundment having a useable capacity of about 600 acre-feet would be needed.

In contrast to the alternate discussed above, the proposed Patoka River Reservoir would provide a single reservoir upstream from Jasper. This structure would be of the multiple purpose type. It would provide storage for water quality control and for municipal and industrial water supply along with its other functions. The proposed Patoka Reservoir should be an impoundment of suitable size to provide for Jasper's municipal and industrial water supply and for quality control downstream from Jasper. It should at the same time satisfy the needs of Huntingburg and Oakland City

and also should provide Winslow with raw water of satisfactory quality. It will be necessary to construct about 3.2 miles of pipeline for Huntingburg and about 2.5 miles of pipeline for Oakland City when those communities need additional water, if Patoka River water is used as a source of additional water.

Construction of the proposed Patoka River Reservoir with storage sufficient to provide for downstream needs would avoid the cost of individual single purpose structures. The storage needed for municipal and industrial water supply is that volume which will be sufficient to provide a minimum flow at Jasper of 16.3 mgd in 1976 and 20.4 mgd in 2010. Owing to the time limitation, sufficiently accurate correlations have not been developed to indicate the precise amount of storage volume needed for municipal and industrial water supply purposes, but during conditions comparable to those of 1953-54, about 12,200 acre-feet of useable storage would be required.

The proposed multiple purpose Patoka Reservoir could provide the total storage needed downstream for municipal and industrial use and for water quality control more efficiently than would single purpose structures for the reason that cost per acre-foot of storage generally decreases as storage volume increases. The cost to provide the needed water by individual impoundments for each community and by a single purpose structure upstream from Jasper for water quality control may be taken as the measure of the benefit to be realized from the satisfaction of these needs by the proposed multiple purpose structure.

Water Supply Benefits

The cost of a single purpose reservoir for municipal and industrial water supply for Jasper in terms of 1963 costs would equal or exceed the cost of Jasper's present reservoir or $250,000. This would not include the benefit of cooling water which has been estimated as having a value of $35,000 annually for 15 mgd or 23 cfs for a nonconsumptive use. The $250,000 reflects the equivalent first cost of 5.4 mgd or 8.4 cfs for municipal and other industrial needs. Adjusted for operation and maintenance and amortized for a period of 50 years, this cost represents an annual value of about $15,000 per year from the benefits of the proposed Patoka River Reservoir.

A single purpose reservoir to provide water for municipal and industrial uses for Huntingburg has been estimated to cost about $142,000. The cost of a pipeline to permit use of Patoka River water has been estimated at about $55,000. Because of lack of time to make a detailed study, annual pumping costs and annual maintenance costs of the single purpose reservoir have not been computed, but it is expected that the net first cost value of $87,000 ($142,000 - $55,000) in terms of 1963 costs may be a fair appraisal of the benefits. With flows provided from the proposed Patoka Reservoir as shown in Table 15, no additional storage would be required by the community. Therefore, adjusted for operation and maintenance costs and amortized for a period of 50 years, the value of benefits to Huntingburg would be about $2,800 per year.

It is anticipated that Oakland City, without the proposed Patoka Reservoir, would need additional storage supply of about 600 acre-feet by or before 1976. It has been estimated that such a structure would cost about $60,000 in terms of 1963 construction costs. The cost of a pipeline necessary to use Patoka River water has been estimated at $43,000. Thus, the net benefit from the multiple purpose structure will be about $17,000 in terms of 1963 construction costs. Adjusted for operation and maintenance costs and amortized for 50 years beginning in 1970, the annual value of the benefits to Oakland City would b about $500.

The total value of water supply benefits enumerated above is about $354,000 in addition to $35,000 per annum for 23 cfs for cooling water and the total annual benefit would be about $58,000.

The amount of the annual benefit of the municipal and industrial water from the proposed reservoir has been computed by converting the net savings in capital cost to an annual basis by amortizing for 25 years at 4 percent, and converting to an annual basis for a 50 year period at 3 percent. Annual operation and maintenance costs of the alternate were added to this figure and annual operation and maintenance of any necessary pipeline were deducted. The resulting benefit figure was then discounted to the year when the supply would become necessary. The benefits to Jasper were discounted to 1971 for a period of 50 years beginning in 1970. The benefits to Huntingburg and Oakland City were discounted to 1980 for a period of 50 years beginning in 1970.

The above estimates are based upon cost per acre-foot of storage in small reservoirs built in southern Indiana in recent years. If suitable sites could not be readily obtained, costs are expected to exceed the estimates given. A more detailed study would result in a more reliable estimate of municipal and industrial water supply benefits from the proposed Patoka Reservoir.

Water Quality Control Benefits

Water for quality control is necessary to provide a water of a suitable quality for downstream needs even though adequate treatment of wastes is being and is expected to continue to be provided so that 85 percent removal of 5-day, 20°C BOD of wastes will be accomplished. It is concluded that the most feasible alternate method of providing a water of suitable quality downstream would be to develop a single purpose reservoir upstream from Jasper for the purpose of supplying water for quality control in the amounts shown in Table 15, at a point downstream from Jasper. This quantity of water would include that discussed previously for steam generator cooling purposes. It would not be in addition to that requirement.

The quantity needed for water quality control below Jasper would range from a minimum seven consecutive day average with a ten year frequency of 33 cfs in 1976 to 68 cfs in 2010. The draft on storage required to yield this needed flow in 2010 would be about 37,600 acre-feet.

The value of flow needed for water quality control would be the capital cost of a reservoir which would provide enough storage to yield 43.6 mgd (67 cfs) in the year 2010 at Jasper. The capital cost of such a reservoir is estimated to be $3,400,000.[11] This cost amortized for a period of 50 years and adjusted for operation and maintenance cost would be about $160,000 per year.

The flows indicated as needed for the various years and uses are shown in Table 15. If flows would be provided as shown at Jasper, it is expected that water of an acceptable quality and adequate quantity would be available in the Patoka River so that it could be used by Jasper, Huntingburg, Winslow, and Oakland City for municipal and industrial water supply purposes.

Even though the quantities of flow shown on Table 15 would be provided at Jasper, it is doubtful that the quality of river water near Princeton would be acceptable as a source of raw water for Princeton due to intervening pollution by acid mine wastes and oil field wastes. However the quality of water at Princeton and in the lower reaches of the Patoka River would be much improved over its present quality by the release of such flows from the proposed reservoir. These flows would also improve the quality of the Wabash River downstream from Mt. Carmel, Illinois. Sufficient data are not available to estimate the probable quality of water at Princeton with the quantities of quality control water shown in Table 15. Data from Indiana's water quality monitoring network shown in Table 2 indicate that a flow of 125 to 200 cfs at Princeton might be needed in the river to provide an acceptable raw water supply for Princeton.

No estimate of the value of the storage needed to provide 125 to 200 cfs at Princeton has been determined. It is believed that much more information should be obtained concerning sources of pollution by mine acids and oil field wastes before any firm answer involving quantity, quality, or value of water is given concerning the Patoka River near Princeton.

In order to assure a satisfactory quality of water released from the proposed Patoka River Reservoir, consideration should be given to multiple level outlets, one near the upper level, one at mid-depth, and another at the lower depths.

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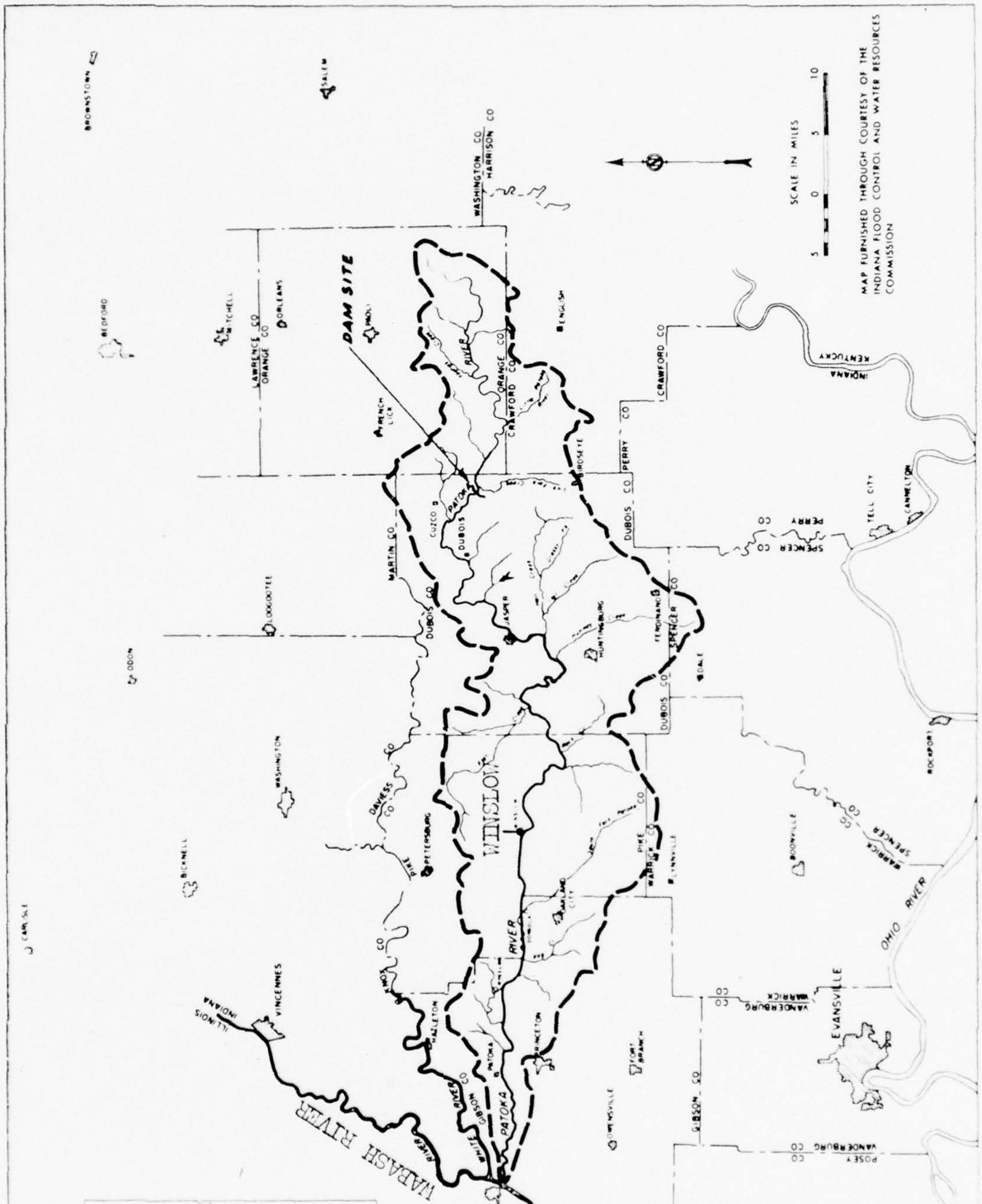

PATOKA RESERVOIR REPORT

PATOKA RIVER BASIN
STATE OF INDIANA

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

OHIO RIVER BASIN PROJECT — EVANSVILLE, INDIANA FIELD STATION

FIGURE I

FEDERAL POWER COMMISSION
REGIONAL OFFICE
610 South Canal Street
Chicago, Illinois 60607

October 21, 1963

Colonel William Roper
District Engineer
U. S. Army Engineer District, Louisville
Corps of Engineers
P. O. Box 59
Louisville 1, Kentucky

Reference: ORLED-B

Dear Colonel Roper:

Herewith is our second bi-monthly report pertaining to the Coordinated Comprehensive Wabash River Basin Study.

In a preliminary study of the Lincoln site at mile 103 on the Embarrass River we assumed that 167,900 acre-feet of storage between elevations 588 and 610 could be used in the interest of power. Tailwater was assumed to be at elevation 543. During the 20-month critical stream flow period, July 1953 to February 1955 inclusive, this storage would provide a minimum regulated flow of 175 cfs and a continuous power output of about 675 kilowatts. An installation of 6,750 kilowatts (considered dependable at 10% plant factor) would permit an average annual energy output of about 21 million kilowatt-hours.

Our economic studies of this project were based on the cost of power facilities consisting of the powerplant, power tunnel and intake and excluded any portion of dam and reservoir costs. The power facilities were assumed to be constructed by the Federal Government at an estimated cost of about $2,900,000. Based on a 50-year life and an interest rate of 3%, the estimated annual cost of the specific power facilities including operation and maintenance would be about $204,000. With power values of $22.50 for capacity and 1.8 mills for energy, based on a privately-financed alternative steam-electric source of power, the annual benefits would be $191,200. The benefit-cost ratio would be about 0.93 to 1.0.

Therefore, we conclude, on the bases of the assumptions adopted, that hydroelectric power at the Lincoln Reservoir site is economically infeasible at this time. Our reports on Clifty Creek, Big Walnut Creek and Richland Creek will follow as requested.

In reviewing what we have reported to you in these first two letters, it appears to me that our two offices cannot yet adopt the position that power at Ellsworth and Lincoln is definitely out of the picture. In the first place, we are not fully satisfied with the power values we have employed, and are currently reviewing this subject. Secondly, a lower plant factor than the 10% we have assumed might well be considered. A lower plant factor would increase the B/C ratios. Then, although as stated we have not considered reservoir costs, we don't know to what extent joint use of storage might be possible. Nor are we certain as to the type of dam that might be built. We have assumed earth dams which give us higher costs for power than concrete dams. On the other hand, low plant factor operation would probably require reregulating dams to be built to reduce surges in the downstream channels, and this would result in higher costs. Your views and those of your Mr. John F. Bruce and others of your staff on these matters would be appreciated. Accordingly, we would like your reaction to selecting a mutually acceptable date for a conference either in Chicago or Louisville before the end of the year -- say after we have completed our first trial runs on each of the five projects and furnished you letters covering this phase of our work.

Sincerely yours,

/s/ Kenneth G. Tower

Kenneth G. Tower
Regional Engineer

Exhibit F-7

FEDERAL POWER COMMISSION

REGIONAL OFFICE
610 South Canal Street
Chicago, Illinois 60607

October 2, 1963

Colonel William Roper
District Engineer
U. S. Army Engineer District, Louisville
Corps of Engineers
P. O. Box 59
Louisville 1, Kentucky

Reference: ORLED-B

Dear Colonel Roper:

Thank you for your letter of August 28, 1963 concerning the work on the Comprehensive Survey of the Wabash River Basin and requesting our views on the power potential of five reservoirs on the Patoka River, Embarrass River, Clifty Creek, Richland Creek and Big Walnut Creek to be incorporated in the second Interim Report on the Wabash River Comprehensive Survey scheduled for January 1964.

In a preliminary study of the Ellsworth Reservoir site at mile 118.3 on the Patoka River we have assumed 140,200 acre-feet of storage capacity in the top of the seasonal pool to be used in the best interest of power. The storage pool in this instance would be between elevation 536 and 515. We have assumed tailwater for our purposes to be at elevation 472. This storage will provide during the 20-month critical stream flow period, June 1953 to January 1955, a minimum regulated flow of 146 cfs and a continuous power output of about 550 kilowatts. An installation of 5,500 kilowatts, all of which is considered dependable, at 10 percent plant factor operation during the critical period, would provide an estimated average annual energy output totalling about 8 million kilowatt-hours.

In our economic studies of this project we have assumed the specific power facilities, excluding any portion of dam and reservoir cost, to be constructed by the Federal Government at an estimated cost of about $2,200,000. This would include powerhouse and equipment and tunnel intake only. The annual cost on these specific power facilities with interest charges of 3 percent and amortization based on a 50-year life would be about $167,000. The annual benefits with power values estimated at $21.00 for capacity and 2.5 mills for energy based on a privately-financed alternative steam-electric source of power would be about $135,000. The benefit-cost ratio would be 0.8 to 1.0.

From these preliminary results, we conclude that the development of hydroelectric power at this site is economically infeasible at this time; however, should the development of this small amount of power be desirable in the future we are of the opinion that the driving of a tunnel through one of the abutments is feasible and would not require any provisions in the initial construction of the proposed reservoir project.

We have examined the topography adjacent to the reservoir for pumped storage potential and are of the opinion that the 200 to 300 feet of head available warrants some consideration of a pumped storage project.

Our next letter pertaining to the five reservoirs you have under consideration at the present time will present our views on the potential of the Lincoln Reservoir on the Embarrass River and will be mailed to you about October 15.

It will be appreciated if you will furnish this Office tailwater rating curves for the remaining four projects.

Sincerely yours,

/s/ Kenneth G. Tower

Kenneth G. Tower
Regional Engineer

FEDERAL POWER COMMISSION

REGIONAL OFFICE
610 South Canal Street
Chicago, Illinois 60607

November 13, 1963

Colonel William Roper
District Engineer
U. S. Army Engineer District, Louisville
Corps of Engineers
P. O. Box 59
Louisville 1, Kentucky

Dear Colonel Roper:

This is our third letter addressed to you pertaining to the Coordinated Comprehensive Wabash River Basin Study. We have studied the power potential of Clifty Creek Reservoir on Clifty Creek at Hartsville, Indiana using the data originally furnished with your letter of August 28 and the alternative data received in your October 22 letter.

Using the original data, we based our study on the assumption that the total storage was to be used solely for power. Thus 18,780 acre-feet of storage between elevations 710 and 730 were assumed used in the interest of power. Tailwater was assumed to be at elevation 670. During the 18-month critical stream flow period, July 1953 to December 1954, inclusive, this storage would provide a minimum regulated flow of 29 cfs and a continuous power output of 102 kilowatts. An installation of 1,020 kilowatts (considered dependable at 10 percent plant factor) would provide an average annual energy output of about 4 million kilowatt-hours.

Our economic studies of this project were based on the costs of specific power facilities only, and excluded any portion of dam and reservoir costs. The power facilities were estimated to cost about $790,000. Annual costs of these facilities would be about $60,000 when based on a 50-year life and interest charges of 3 percent. With power values of $21.50 per kw-yr. for capacity and 1.8 mills for energy, based on a privately-financed alternative steam-electric source of power, the annual benefits would be about $29,000. The benefit-cost ratio would be about 0.48 to 1.0.

Exhibit F-7

Using the October 22 data, we assumed that 10,860 acre-feet of storage between elevations 705 and 720 would be used for power. During the 18-month critical stream flow period, a minimum regulated flow of 22 cfs and a continuous power output of 60 kilowatts would be provided by this storage. An installation of 600 kilowatts, all of which is considered dependable (at 10 percent plant factor) would provide an estimated average annual energy output of about 3 million kilowatt-hours.

In our economic studies the specific power facilities are estimated to cost about $738,000. These facilities would be constructed by the Federal Government and would include powerhouse and equipment and tunnel intake only. The estimated annual cost with interest charges of 3 percent and amortization based on a 50-year life would be about $53,000. The annual benefits with power values the same as above would be about $18,000. The benefit-cost ratio would be about 0.33 to 1.0.

Based on the results of these preliminary studies of the Clifty Creek Reservoir site, it is concluded that the development of the small power potential at this site is economically infeasible now and in the foreseeable future.

With regard to the Richland and Big Walnut Creek Reservoirs our comments will not be furnished until such time as you indicate their need.

Sincerely yours,

/s/ Kenneth G. Tower

Kenneth G. Tower
Regional Engineer

COPY

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
611 N. Park Ave., Rm. 506
Indianapolis 4, Indiana

December 13, 1963

Refer to File No. ORLED-B

Colonel W. Roper, District Engineer
U. S. Army Engineer District, Louisville
Corps of Engineers
P. O. Box 59
Louisville 1, Kentucky

Dear Colonel Roper:

Reference is made to your letter of 14 November 1963, in which you acknowledged recommendations made by the U. S. Forest Service relative to a reservoir project on Patoka River on which you are preparing information for the current interim report.

While we would agree with your opinion that the proposals presented by the Forest Service impact report should be given detailed consideration at the time of detailed design stages, if and when the project is authorized, there is a relationship to land use and management in the views presented in Mr. Barry's letter. It is understood that the management of such lands is a policy matter which has not been fully resolved by higher authority in our respective Departments. However, in this case, since this is a matter of vital concern to our coordination of efforts in plans for this project, the interim report should recognize this need for facilitating management.

We are not presenting additional information for inclusion in the current interim report, but will provide further recommendations on use and management of these lands if the project is authorized for development.

Very truly yours,

/s/ C. E. Swain

C. E. Swain
State Conservationist

cc: Paul St. Amant, Assistant Regional Forester, FS, Milwaukee, Wisc.
Howard C. Cook, Forest Supervisor, FS, Redford, Indiana

Exhibit F-8

COPY

ORLED-B 14 November 1963

Mr. Joseph J. Barry
Acting Forest Supervisor
Forest Service
U. S. Department of Agriculture
Wayne-Hoosier National Forests
Bedford, Indiana

Dear Mr. Barry:

Reference is made to your letter 2550, dated 29 October 1963, indicating the responsibilities of the Forest Service for forest land management as assigned by Senate Document #97 and the Multiple Use-Sustained Yield Act of 1960. The aims and objectives of the Forest Service as briefly outlined from your impact report on Patoka Reservoir are the same aims and objectives of the Corps of Engineers in our current Wabash River Basin Comprehensive Study.

The Patoka Reservoir project will be included in an interim report scheduled for completion by the Louisville District in January 1964. The interim report will be prepared in sufficient scope to permit Congressional authorization of the recommended projects. This report will indicate the lands required for all project purposes, including lands for recreation and lands considered necessary to replace game propagating areas which may be inundated by the project. The specific location of these lands will not be designated in the interim report; however, the criteria for their siting will be set forth, generally in conformance with recommendations of the U. S. Fish and Wildlife Service.

The specific location of public use lands and management thereof can best be determined in detailed design stages, if and when the project is authorized. The management of these lands, as proposed in your referenced letter, is a policy matter that may require coordination at higher Department of Agriculture and Corps of Engineers levels. In these regards Mr. Swain, the designated Department of Agriculture coordinator for the Wabash Comprehensive Study, is being asked to present such Department of Agriculture opinions as he considers appropriate for inclusion in our interim report.

COPY

ORLED-B 14 November 1963

Mr. Joseph J. Barry

A copy of the letter sent to Mr. Swain is inclosed for your information.

Very truly yours,

W. ROPER
Colonel, Corps of Engineers
District Engineer

1 Incl
Ltr to Mr. Swain

Copy furnished
Mr. C. E. Swain
State Conservationist
Soil Conservation Service
U. S. Department of Agriculture
611 North Park Avenue
Indianapolis 4, Indiana

Exhibit F-8

COPY

ORLED-B

14 November 1963

Mr. C. E. Swain
State Conservationist
Soil Conservation Service
U. S. Department of Agriculture
611 North Park Avenue, Room 506
Indianapolis 4, Indiana

Dear Mr. Swain:

Reference is made to the inclosed copies of (1) letter 2550 from Mr. Joseph J. Barry of the U. S. Forest Service and (2) our reply to Mr. Barry. Both relate to a reservoir project on Patoka River which is under consideration by our agencies.

The subject matter of these letters relates primarily to land use and management rather than plans for, or economics of, project development. It is our opinion that the proposals, to be presented in the Forest Service's impact report, should be deferred for detailed consideration in detailed design stages, if and when the project is authorized. If you desire to include any land use or management views of the Department of Agriculture in the current interim report, please forward them as soon as possible. Our schedule calls for submission of this report in final form by this office on 2 January 1964.

Very truly yours,

W. ROPER
Colonel, Corps of Engineers
District Engineer

2 Incl
1. Ltr 2550 of Mr. Barry, U.S.Forest Service
2. Ltr ORLED-B, 14 Nov 1963 (our reply to to Mr. Barry)

Exhibit F-8

COPY

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Wayne-Hoosier National Forests

BEDFORD, INDIANA In Reply Refer To

October 29, 1963 2550

Colonel Willard Roper
Corps of Engineers
830 West Broadway
Louisville 3, Kentucky

Dear Colonel Roper:

As you know, the proposed Patoka (Ellsworth) Reservoir in South-Central Indiana will lie within the Administrative boundaries of the Hoosier National Forest. Senate Document #97 and the Multiple Use-Sustained Yield Act of 1960 assign the U. S. Forest Service responsibility for (1) assuring adequate evaluation of all anticipated impacts this project will have on national forest development and administrative programs and (2) for assuring both recognition and incorporation into the comprehensive development plan a full analysis of the potential for development of related land resources, both public and private.

In fulfillment of this responsibility, the Hoosier National Forest is preparing a report on impacts the Patoka project will have on national forest and private development activities in this area. This letter will cover the essentials of our report; a more detailed report will follow later.

Our information is that the primary dam will be located in Section 14, T 1 S, R 3 W, 2nd PM. A secondary dam or dike will be located in the adjacent Section 15. Maximum drawdown will be to elevation 506 M.S.L. with a minimum pool of about 2,050 acres. The normal summer pool will be at elevation 536 with an area of about 8,800 acres. The maximum flood pool will cover 11,850 acres at elevation 550. The dam crest will be at elevation 567. The primary purpose of the project is flood control but recreation and low flow augmentation features will be included.

We recommend that the entire flowage be taken in fee rather than by easement. Public control of the entire shoreline will help assure that irresponsible individuals do not endanger project works and benefits with improper sewage disposal, inadequately moored boats, docks, and rafts, and other unsightly and hazardous developments.

Exhibit F-8

Development and administration of these project-related public lands will be most effectively and economically accomplished by placing these lands under the jurisdiction of a single public land management agency. Because the Forest Service already has an effective administrative structure established in the area, and because they presently administer lands which will adjoin project lands, we recommend that all lands not needed for flood control purposes be incorporated into the Hoosier National Forest System. Transfer of these lands can be accomplished under provisions of the Act of July 26, 1956 (70 STAT. 656; 16 U. S. C. 505a, 505b) which states that "The Secretary of Agriculture with respect to National Forest Lands and the Secretary of a Military Department with respect to lands under control of that Department which lie within or adjacent to the exterior boundaries of a National Forest are authorized . . . to interchange such lands . . . without reimbursement or transfer of funds whenever they shall determine that such interchange will facilitate land management and will provide maximum use thereof for authorized purposes . . ." Inclusion of these lands in the present National Forest System will provide for optimum development of project-related soil, water, timber, fish and wildlife, and recreation resources which will accrue additional benefits to the project.

The Forest Service and Corps of Engineers will need to consult with each other regarding overall plans for developing and administering public recreation use and facilities.

Wildlife habitat mitigating measures will have to be provided to the extent that sufficient land suitable for habitat will be acquired as a part of the project to replace land lost by flooding. The State Division of Fish and Game and the U. S. Fish and Wildlife Service in cooperation with the Forest Service and Corps of Engineers should select specific areas around the reservoir for replacement of project-inundated habitat. Management of these lands should be the responsibility of the Forest Service under provisions of the Fish and Wildlife Coordination Act PL 85-624.

Facilities and services inundated or impaired by the project should be relocated and restored at project cost so that a level of service equivalent to that existing prior to construction will be maintained. Any increased costs of wildfire protection and road maintenance created by the project should be borne by the construction agency. Details should be worked out with the responsible Federal, State, and local agencies.

These are the principal recommendations we have to make on the basis of our impact survey. We will forward a more detailed report when it is prepared.

Sincerely

HOWARD C. COOK
Forest Supervisor

/s/ Joseph J. Barry
By: Joseph J. Barry, Acting

Exhibit F-8

COPY

CITY OF CHARLESTON
Coles County
Charleston, Illinois

March 4, 1964

Mr. John F. Bruce
Ass't Chief, Engineering Division,
Basin Planning
U. S. Army Engineer District, Louisville
830 West Broadway
Louisville, Kentucky 40201

Dear Sir:

It is understood by the city officials of Charleston, Illinois that, if Lincoln Reservoir is constructed as a Federal project, it will inundate the Charleston water supply reservoir and raw water intakes. It is further understood that the Federal government will replace at Federal expense facilities equal in capacity to those inundated. The facilities to be inundated are sufficient for some time to come, but in looking to the future it is apparent that it would be in the interest of Charleston to reserve additional storage facilities in Lincoln Reservoir.

It is the intent of the present City Government that additional acre feet of storage capacity will be purchased by the city.

Yours very truly,

/s/ William Woods
William Woods, Mayor

EXHIBIT F-9

COPY

INDIANA FLOOD CONTROL AND WATER RESOURCES COMMISSION
606 Indiana State Office Building
100 North Senate Avenue
Indianapolis 4, Indiana

Telephone: MElrose 3-5267

December 24, 1963

Colonel W. Roper
District Engineer
Louisville District Office
Corps of Engineers, U.S. Army
830 West Broadway
Louisville 3, Kentucky

Dear Colonel Roper:

The State of Indiana is deeply concerned about the development of its water resources not only to take care of present needs but to make sure that the needs of the future can be adequately met through prudent development of current reservoir projects and proper management of water through the years to come. Past experience has indicated clearly that the one factor that has had the most effect in deterring the economic growth and prosperity of the southern part of Indiana has been the uncertainty of water supplies. Many communities have been unable to support any additional growth for past decades because sufficient water supplies have not been developed to meet present day needs and the communities affected have not been financially able to bring about such development.

In commenting on this problem at the recent Third Annual Governor's Conference on Water, Governor Welsh stated, "Probably in no other area is long-range planning more practical and more necessary than in assuring for future years adequate water supply and the most efficient and socially desirable uses of these resources. --- But even more important, we cannot expect the future to take care of itself. We today must have the prudence and the foresight to recognize the problems that would be created by our failure to plan now for tomorrow's needs. Just as we today are paying the price in property damage and lost opportunities because there was neither sufficient understanding nor action to guard against rampaging waters and inadequate or badly distributed water supplies in past decades. Because this was the nature of the past, is not enough justification to make it our policy for the future."

At the same Conference on Water it was abundantly clear that there is general public acceptance of the fact that reservoir sites must be developed to their maximum potential for all uses of water if the future welfare of the state is to be protected.

The Patoka River basin is a good example of the value of developing an adequate supply of water. All counties in the basin have been losing population except Dubois County, and the gain in that county has been due principally to the growth of the City of Jasper. In the period 1940 to 1950, Jasper increased in population by 174 persons. Jasper had been plagued for years by water shortages and during the 1953-1954 drought was threatened with the loss of some of its key industries because of an inadequate water supply for industrial needs. Jasper then built a water supply reservoir to satisfy its requirements for a few years in the future. Between 1950 and 1960 the population of Jasper increased by 1,522 persons or nearly 30 per cent which is considerably greater than the average 18.5 per cent for the state as a whole. Water enabled old industries to expand and new businesses to be established in Jasper and thereby increased job opportunities.

It is the State's position that a better water supply can boom the economy of the whole Patoka River basin.

The Ellsworth Reservoir can provide the opportunity to diminish flood damage and increase water supplies along the whole length of the Patoka River. Therefore, the reservoir should be developed to the maximum potential of the site in order that it may contribute to the needs of the future to a maximum degree.

The survey report on Ellsworth Reservoir, that the U. S. Army Engineers District, Louisville, is about to complete, should indicate that the State of Indiana is anxious to have the water supply storage in the reservoir developed to its maximum practical limit. There is a statutory indication of the legislative intent that this should be done with respect to Ellsworth Reservoir in particular and with other reservoirs in general.

Chapter 37, Indiana Acts of 1963 (Special Session), dedicates a portion of the State cigarette tax to the development of multiple-purpose reservoirs by the Indiana Flood Control and Water Resources Commission and specifically directs the Commission to consider the construction of a reservoir on the Patoka River.

Chapter 342, Indiana Acts of 1963, authorizes the Indiana Flood Control and Water Resources Commission to sell water from water supply storage in reservoir impoundments or portions thereof that have been or may be financed by the State of Indiana. The Act also creates a "Water Resources Development Fund" into which the proceeds from the

sale of water shall be deposited and which shall be used as a revolving fund for the development of new reservoirs.

The Commission in operating under the provisions of these acts desires to acquire the rights to the water supply storage in Ellsworth Reservoir and, if the reservoir is authorized as a federal project, will have a bill presented in the State Legislature at the proper time for an appropriation to pay for such storage in compliance with the requirements of the Federal Water Supply Act of 1958.

In recognizing the need for coordination of storage requirements for water supply and water quality control, the Commission at its meeting on December 20, 1963 appointed a special committee to study this problem and recommend policy. As this study may take some time, it is desired that the question of exact division of allocated storage between water supply and water quality control be left for later decision and that initially the conservation storage in Ellsworth Reservoir be allocated to water supply purposes but subject to such modification as may be desired after more detailed study.

It is extremely important that the State's interest in developing the maximum potential of the site and its right to the maximum feasible water supply storage be protected.

Very truly yours,

/s/ J. I. Perrey
J. I. Perrey
Chief Engineer

JIP:gm

(Ed. Note: Ellsworth is another name for Patoka Reservoir.)